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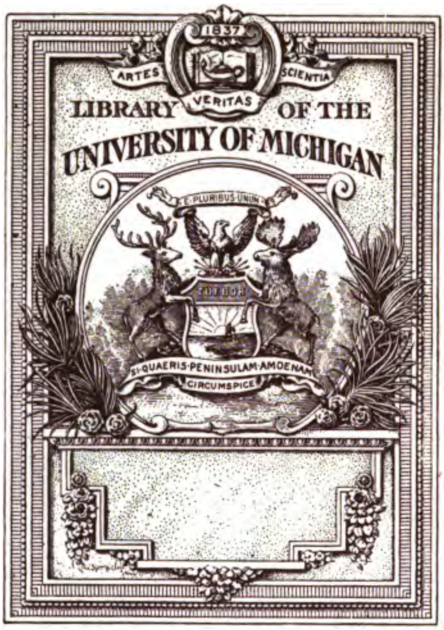
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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF FORESTRY—BULLETIN No. 50.

GIFFORD PINCHOT, Forester.

CROSS-TIE FORMS AND RAIL FASTENINGS, WITH SPECIAL REFERENCE TO TREATED TIMBERS.

BY

HERMANN VON SCHRENK,
IN CHARGE OF FOREST PRODUCTS, BUREAU OF FORESTRY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1904.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Forestry,
Washington, D. C., May 7, 1904.

Sir: I have the honor to transmit herewith a report entitled "Cross-Tie Forms and Rail Fastenings, with Special Reference to Treated Timbers," by Hermann von Schrenk, in charge of Forest Products in the Bureau of Forestry, and to recommend its publication as Bulletin No. 50 of the Bureau of Forestry.

The five plates and seventy-one text figures accompanying this report are necessary for its proper illustration.

Very respectfully,

Gifford Pinchot,
Forester.

Hon. James Wilson,
Secretary of Agriculture.

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CROSS-TIE FORMS AND RAIL FASTENINGS, WITH SPECIAL REFERENCE TO TREATED TIMBERS.

INTRODUCTION.

The enormous rate of consumption of timber for railroad ties, and to a less extent for telegraph poles and other timbers used in railroad work, is giving serious concern to all railroad men at the present day. Vast quantities of wood are taken from our forest lands every year without any regard for the future. For the last ten or fifteen years the Government foresters, the journals devoted to railroad interests, and more recently the lumber-trade journals have been calling attention to the increasing amount of timber used for ties, and have been urging that, in view of the rising prices and diminishing supply already evident, some steps should be taken to provide for future needs.

Various suggestions have been made as to how the question of a future supply of ties might be solved. Some have suggested (and this suggestion is made with increasing frequency) that ties should be made out of materials other than wood. Granite ties were among the earliest substitutes offered; they were used for some time in Dublin, Ireland, and on the old Boston and Lowell Railroad in Massachusetts. For some fifty years various forms of metal ties have been suggested, and a large number of steel ties have been tried in various countries. In recent years concrete ties have been made, and some of these are now being tested. These ties are either composed wholly of concrete or are provided with wooden blocks embedded in concrete to serve as a rail bearing. There is also a steel concrete tie, constructed of concrete with strengthening steel rods embedded in it, which likewise sometimes has wooden rail bearings.

The advocates of steel ties and concrete ties urge that when these ties are adopted there will be no necessity for worrying about a future supply of wood. The problem of whether or not railroads can use steel or concrete ties, however, is not one which comes within the province of the forester. It is an engineering problem, pure and simple. If the engineer finds that he can use steel or concrete more economically than wood, he will certainly do so without any urging from those interested in the perpetuation of forest resources. It is not, therefore, the present intention to discuss whether or not a concrete or steel tie is a good thing, but to deal with the fact that most of the railroads to-day are using wood, and, so far as the writer is able to judge from present tendencies, are likely to continue to do so for some time. Given this probability, the questions which it behooves us to consider are: What are the methods, if any, which can be adopted toward the more economical use of the resources of timber now at hand, and in what way can we provide for a future supply?

The wasteful methods employed in cutting ties in the past have called forth many protests and suggestions as to how this waste might be checked. An effort was made by Hon. Norman J. Colman, as Commissioner of Agriculture, in December, 1887, to induce railroad companies to use the existing timber supplies more economically.

In a circular issued at that time, the Commissioner said, "Millions of feet of tanbark or chestnut oak are rotting in the forest after being stripped of their bark, because their value for cross-ties is not known or is underestimated in many regions."[a] He appealed to the railroad companies to use this wood so far as possible for ties, in order not only to avoid this waste but also to preserve the supply of white oak. His appeal resulted in a brief effort on the part of some companies, but this lasted only a short time.

The planting of trees has from time to time engaged the attention of farsighted men. A notable example is a grove of catalpa trees planted at Farlington, Kans., in 1880, by Major Hunnewell, then connected with the Kansas City, Fort Scott and Memphis Railroad. It certainly is important for every large user of timber to encourage the replanting of denuded areas with such species of trees as will be most useful in the particular region. The question of future supply, however, is not within the province of the present bulletin.

In spite of the general urging to economy, and in spite of the general acceptance of the fact that timber has become scarcer and more expensive from year to year, very little progress seems to have been made toward solving, even partially, the question as to what is to be done to secure ties in the future. Ties are still bought and sold as they were years ago. It is, however, becoming harder every year for the purchasing agent to call for 500,000 first-class ties of white oak, with the certainty of getting them. The unwelcome fact that ties are scarcer has already presented itself, and it will continue to do so with rapidly increasing force. It is believed that the next few years will see a very radical change in the attitude of railroad men toward the tie problem, and, therefore, toward forest problems. The rapid introduction of treated timbers is the first step in this change. Many have protested against the use of treated woods, and some are still doing so, but all will eventually come to use them. The advisability of using treated woods is no longer an open question; their use is a matter of necessity to-day, and must be regarded as such in meeting present problems.

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[a] Bull. No. 3, Division of Forestry, U. S. Dept. of Agriculture, p. 52.

The use of chemically treated woods is an innovation on most railroads, and it has come to many so suddenly that they are not prepared to grasp the exact nature of the change they are making. The writer firmly believes that unless the problems discussed below are considered, many if not all users of chemically treated ties will be disappointed. Ties made of red oak and the soft pines will not last, using that term in its broadest sense, unless they are cared for in other ways besides chemical treatment. Few will then ask, "Why did they not last?" The mere fact that the treated ties had to be removed from service will be sufficient for many to blame the timber and the treatment. But the chemical treatment of timber is no longer an experiment. One can treat timber so as to prevent it from *decaying*, and there ought to be no hesitation in adopting the use of treated timbers on most railroads to-day.

Two subjects of decided importance in a consideration of the tie question at the present time will be dealt with, viz. tie forms and rail fastenings:

TIE FORMS.

TREATED TIES MAKE POSSIBLE NEW FORMS.

The suggestions made for economy in the cutting of ties have been largely in the direction of preventing wasteful cutting. The manner in which they have been cut from trees has been largely determined by the ease and rapidity with which ties could be made, and by the knowledge that certain portions of a log were more serviceable for tie purposes than others. Ties were usually made out of hard wood, using only the best and straightest live trees. No attention was paid to the waste incurred by cutting off all the sapwood top sections, by leaving dead trees, etc. But with the introduction of treated ties certain new developments in tie making have taken place. Treated ties allow the use of sapwood, of sawed dead timber, and of sawed ties. Consequently tie forms which were altogether impracticable under the old methods are now within the field of possibility, and must be considered on their merits.

THE PRESENT SHAPE OF TIES IN THE UNITED STATES.

The ties now in use in this country are practically all rectangular in cross section. They vary considerably in dimensions, as indicated by the following list of specifications of some representative railroads:

TABLE I.—*Tie specifications.*

Railroad.	Kind of timber.	Length.	Breadth of face.	Thickness.
		Feet.	*Inches.*	*Inches.*
Illinois Central	White oak	8	8	6
Northern Pacific	do	8	8-9	7
Do	do	8	7	7
Do	do	8	6	7
Union Pacific	Western yellow pine	8.08	8-10	7-8
Burlington	White oak	8	8	6-7
Do	Cedar	8	8	6-7
St. Louis and San Francisco	White oak	8	8	6
Missouri Pacific	Pole ties, green	7.91-8.08	8-12	6-7
Do	Split ties, green	7.83-8.17	8-10	6-7
Do	Pole ties, dry	7.91-8.08	7.75-12	5.75-7
Do	Split ties, dry	7.83-8.17	7.75-10	5.75-7
Atchison, Topeka and Santa Fe	Hewn longleaf, shortleaf, or loblolly pine.	8	8	6
Do	Same, timbers sawed	8	8	6

Ties must be of a certain length, breadth, and thickness, for several reasons. In the first place the tie serves as a beam supporting a certain load which is concentrated at two points—that is, under the rails. This beam is supposed to rest for its entire length on a substratum of ballast, but in reality the larger portion of the pressure is borne by the part located between the rails. The length is determined largely by the gauge. For many years it was uniformly 8 feet. During the last few years several roads, some of the Eastern roads in particular, have increased this length to 8.5 feet, believing that the increased loads passing over tracks required a longer tie. The reason for this change is also stated to be that by increasing the length the track was less liable to be center bound.

Recent stremmatograph tests made for the New York Central and Hudson River Railroad by Dr. P. H. Dudley have shown that large ties make the most stable roadbed. Doctor Dudley has kindly contributed the following by letter:

> The comparison in bending moments per pound of load of the locomotive on 8 foot 6 inch by 9 by 9 inch cross-ties is from 9 to 15 per cent higher than on 8 foot 6 inch by 7 by 9 inch cross-ties. The longer and thicker cross-ties distribute the load of the passing locomotive laterally to a greater width of the roadbed, therefore giving less intensity of pressure per bearing surface, which is a decided advantage. With cross-ties 9 feet long, 9 inches wide, and 7 inches thick there would still be a slight increase over cross-ties 8 feet 6 inches long by 9 by 7 inches.
>
> Only a few results have been deduced by these elaborate calculations, but they show a decided advantage by increasing the thickness and length of the cross-tie over those 8 feet in length, 9 inches wide, and 6 inches in thickness. The same

number of cubic feet of timber per rail length of mile in long and thick cross-ties would be more efficient for heavy wheel loads than the same number of cubic feet in cross-ties of smaller dimensions.

The breadth of the first ties was but 6 inches. This breadth has been gradually increased until now many roads use ties 9 and 10 inches in width. Tie-plates are used on some of these broad ties, but on the majority of them they are not. Until within a few years the average thickness of ties was 6 inches. This thickness was recently increased to 6½ and 7 inches, and a discussion is even now going on as to whether it will not be desirable to increase the thickness still further. This increase is made because it is feared that the enormously increased weight of engines and cars now requires a stronger piece of timber under the rails than the lighter equipment of the past. This is particularly true where tracks are liable to be center-bound.

NEW SPECIFICATIONS AND CLASSIFICATION OF TIES SUGGESTED.

Changes in specifications have been of a haphazard sort, guided largely by assumptions that the smaller standards were insufficient. There are very few data at hand showing the relation between the loads which a tie is required to bear and the strength of the tie actually used. The standards which are in use at the present time are in many respects exceedingly unsatisfactory. Each road has its own standards, and hardly two agree. While it is certainly true that the requirements may differ on different roads, it is not true that these differences are great enough to justify so many standards. It has repeatedly been urged that the classification of ties into first, second, and third class has very little significance, because a first-class tie on one road may be a second-class tie on another, and vice versa. The large number of standards in use, while it has not seriously interfered with the lumber trade in the past, is beginning to do so at the present time. It is extremely difficult for a lumber company to supply 3 or 4 kinds of first-class ties, and it is also more expensive to the individual roads.

To obviate this difficulty it is proposed that the so-called first, second, and third class ties and the class "cull tie" be abolished, and the following classification be substituted:[a]

TABLE II.—*Proposed tie classification.*

Class.	Breadth.	Thickness.	Length.
	Inches.	*Inches.*	*Feet.*
A	9	7	8, 8.5, or 9
B	8	7	Do.
C	9	6	Do.
D	8	6	Do.
E	7	6	Do.
F	6	6	Do.

---

[a] This classification was adopted by the American Engineering and Maintenance of Way Association at its meeting in Chicago, March 16, 1904. (See Vol. V of the Proceedings of this Society.)

The number of classes might be extended as far as necessary. The advantage which a classification of this kind would have over the present system of first, second, and third class would be that A, B, and C would stand for a definite size, which in the course of time would come to be recognized just as the lumber standards are to-day. This classification would enable a lumberman to get out a number of orders at the same time without undue loss of time or expense.

One of the most important effects of a classification of this kind would be to throw out the cull tie. There does not seem to be any good reason why there should be cull ties, any more than decayed ties. The cull tie end of the tie business, as at present conducted, is unfair both to the railroad man, who, as a rule, does not want these ties, but is practically forced to take them up to a certain percentage of the total number of ties contracted for, and to the man who furnishes them at a price far below the value of the timber. For example, for a tie 6 by 8 inches by 8 feet, which grades as a first-class tie, 30 cents is paid, while a tie 6 by 7 inches by 8 feet is usually classed as a cull tie, for which only 15 cents is paid. The tie maker usually does not get anything for the cull tie. The only reason why the lumberman is willing to take 15 cents for such a tie is that he would rather get that than nothing. The only reason why the railroad companies take such a tie is because it is found by experience that small ties will be brought in with a large lot of those of the required dimension. These small ties the railroads use for side tracks. The making of cull ties is a matter which could largely be prevented. It results in the demoralization of the tie trade, and is at present the most unsatisfactory feature of it. Under the proposed scheme of classification the present cull ties, wherever there was a market for smaller sizes, would readily fall into one of the classes near the bottom of the table, and they would be paid for on a regular scale, at a price proportionate to their real value.

LIVE AND DEAD TIMBER.

In most of the tie specifications now used the following clause occurs: "All ties shall be made out of live * * * timber." In most forests there is more or less dead timber. Some trees are blown over, others are killed by root diseases, others by borers girdling the trees under the bark, and a still larger number by fire. In many of these trees the wood of the trunk is perfectly sound, and remains so for many years. There is absolutely no reason why such dead timber should not be used for ties, especially when these are to be treated, provided always that the dead timber is sound. The mere fact that timber is dead should not cause it to be discriminated against for tie purposes. A rigid examination would show that all heartwood of trees is *dead* wood, in the sense that it is no longer alive. Defective dead timber can be shut out by providing that "timber which is decayed or doty, affected with red-heart, split, brashy, heart or ring shaken, very knotty, or full of worm holes shall be rigidly excluded." Ties made from dead bull pine in South Dakota are giving good service. Test ties of this timber, which were treated with zinc chlorid and placed in southeastern Texas in November, 1902, show absolutely no sign of decay, while untreated ties of "live" hemlock, beech, tamarack, etc., after they had been in place but twelve months in the same region, were partially, and in some cases wholly, decayed. One can, therefore, safely assert that a tie made out of sound dead wood is a good tie, especially when treated.

A modified tie specification would, therefore, read, "All ties should be made from sound, straight timber, which must be free from decay, dote, red-heart, heart or ring shakes, worm holes or beetle holes, and excessive knots, and which must not be brashy."

It is believed to be impracticable at the present time to establish tie standards for various sections in the United States. The sizes which will be used will be, as they have been in the past, largely a matter of individual usage and precedent. This would, however, not militate against the adoption of the scheme of classification proposed above. The railroad wanting large ties could specify class "A," and another could specify class "B," according to the needs of each road.

IS IT DESIRABLE TO DECREASE NUMBER OF TIES PER MILE OF TRACK?

Considerable discussion is at present going on as to the advisability of decreasing the number of ties laid per rail length. This discussion is largely prompted by motives of economy. The practice of laying a certain number of ties per rail length, which has found universal acceptance in the United States, is due to the necessity of providing for a stable track. In Europe, where fewer ties are laid, the smaller weight of the machinery and cars used no doubt justifies the smaller number of ties. There is no question that the number now laid per rail length in this country ought not to be decreased, provided the tie form remains the same as at the present time. What is wanted is a more stable track, one which will give greater bearing surface and which will be correspondingly safer for trains moving at a high speed than the track as at present constructed. It has been claimed that with the increased stiffness of the heavier rails now coming into use it is no longer necessary to have the ties spaced so closely as they were in the past. While this is no doubt true, one must not forget that the spacing of ties is determined by two factors: First, the amount of bearing of the rail on the tie, and, second, the amount of bearing of the tie, or, in other words, the bearing of the whole track on the ballast. While it is agreed that the number of ties per rail length could possibly be reduced, so far as the safety of the bearing of the rail on the tie (using the stiffer rail) is concerned, such a reduction would mean less bearing surface on the ballast. In view of the fact that what is being sought after is increased stability of the whole track on the ballast, a reduction in the number of ties would result in the very opposite of what is wanted. An ideally constructed track would consist of rails resting on ties placed close together, which would practically mean a continuous transmission of the load from the rail to the substratum. It is evident, therefore, that a reduction of the bearing surface on the ballast is undesirable, and the question, "Should the number of ties of the present form now laid per rail length be decreased?" ought to be answered decidedly in the negative.

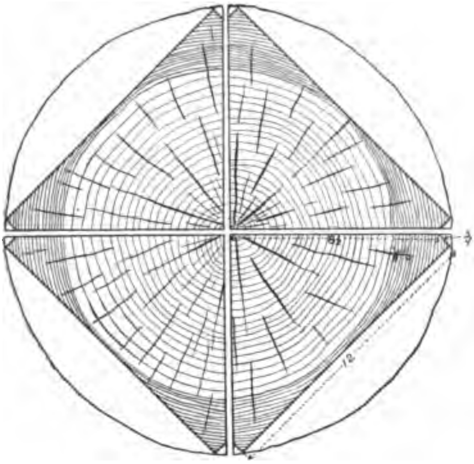

FIG. 1.—Manner of cutting four triangular ties from a tree.

NEW TYPES OF TIES.

Several attempts have been made to change the shapes of ties. In Europe the longitudinal tie, after having been tried for many years, has been practically abandoned. During the last year a new form of tie has been adopted by the Great Northern Railroad. This tie has a triangular shape, as shown in fig. 1. The reason for its adoption was largely one of economy. By using a triangular tie four ties can be cut from a cross section of a tree which ordinarily would have made but two, as indicated in fig. 1. In practice, however, a good many of these ties have been cut two from a log, as shown in fig. 2. While it is no doubt true that more ties would be made per tree of this form than of the square form, this form is nevertheless an extremely undesirable one. The ties are laid in the track with the point down, the rail resting on the broad base of the triangle. When cut two from the cross section of a log (fig. 2), these ties check on the upper surface as the rings of wood straighten out,

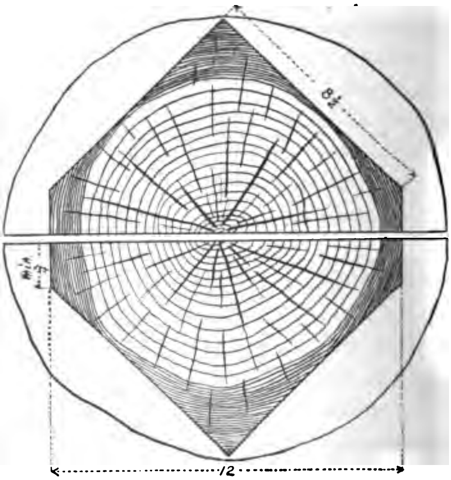

FIG. 2.—Triangular ties cut two from a tree, yielding poor ties.

and the result is that many of the rings break off, making this an extremely dangerous tie form. This is especially true if the spikes are driven into the tie at any point other than the exact center. The chief objection to these ties, however, is that they do not increase the bearing of the base of the tie on the ballast but rather decrease it, so that a track laid with them has less stability than one laid with the ordinary square ties. A recent inspection of a section of track laid with these ties alternately with the usual rectangular ties showed many of them suspended from the rail between two rectangular ties which rested on the ballast, held in position by the spike and offering no support to the rail. It is believed that a tie of this character is an experiment in absolutely the wrong direction.

In seeking for new shapes of ties the first consideration should be to secure at least the same bearing surface on the ballast which the present ties have, and preferably very much more. It is believed by the writer that the present thickness of ties is one which will probably not be increased to any extent even with an increased load, and the same may be asserted of the length. Any changes which may be made will probably be in the two bearing surfaces, namely, the one under the rail and the one on the ballast. With light rails, the present bearing surface of 8 to 9 inches under the rail is necessary where ties are used without tie-plates. The broad tie gives greater bearing surface to the base of the rail, and greater safety to the track.

The heavier rails now coming into general use, because of their increased stiffness, no longer require the same amount of bearing surface on the tie as the lighter rails. It is generally agreed that a reduction in the bearing surface of the rail on the tie may be effected with safety, provided the same kinds of timbers are used as in the past. The only point which has been questioned is whether the softer timbers which are now coming to be employed—that is, timbers like red oak, loblolly pine, etc., in which the sapwood is utilized (it being taken for granted that all of these ties are treated), could be used safely with any bearing surface less than the customary 8 or 9 inches. It has been generally conceded that these timbers could not be used safely without some form of tie-plate, and at the present time most of the roads which have taken up the softer timbers are actually using tie-plates of one kind or another.

While it is probable that stiffer rails will reduce the cutting action of the rail on the tie to a minimum, there seems to be no doubt that some form of tie-plate will be necessary with soft woods, even when a stiff rail is used. By using the stiffer rail, which has a broad base, the tie-plate no longer need distribute the weight, as with the lighter rails, or at least that is a minor function. Its chief function on the soft wood tie with stiff rails will be to prevent wear, and for this purpose some form of plate, either of iron or of wood, will be indispensable.

If we consider the manner in which the load is distributed from the base of a rail resting on a 5-inch plate, which in turn rests on a tie 8 inches broad, we shall find that the lines of force acting from such a tie-plate are distributed on the ballast as indicated in fig. 3. The active portion of the tie, in other words, is practically of a trapezoidal shape, with the upper line of the trapezoid 5 inches long, and the lower 8 inches. The portions of the tie outside of this trapezoid are, so far as the bearing qualities of the tie are concerned, useless.

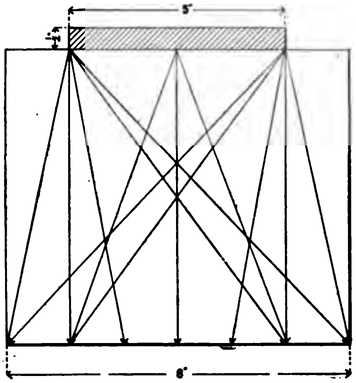

FIG. 3.—Manner in which the lines of force are distributed from a 5-inch tie-plate to the base of a tie 8 inches wide.

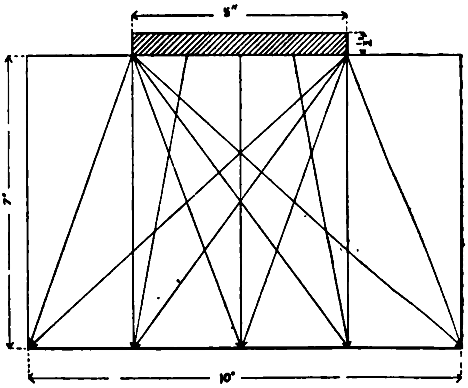

FIG. 4.—Manner in which the lines of force are distributed from 5-inch tie-plate to the base of a tie 10 inches wide.

Keeping in mind the desirability of an increased bearing surface on the ballast, and the fact that the top bearing surface need be only 5 inches when a tie-plate is used, it is suggested that a type of tie with a top-bearing surface of about 6 inches and a base bearing surface of anywhere from 8 to 12 inches will not only give a sufficient bearing surface for the rail, but will also give a very much more stable tie on the ballast. Such a tie would correspond to the type shown in fig. 5, to which may be given the name of the half-round tie. Fig. 4 shows the distribution of the lines of force in this tie. It is evident that the lines of force here have a very much greater extent on the base, and that nothing has been lost in the amount of bearing surface which the rail has on the top of the tie. This form would not only give a greater

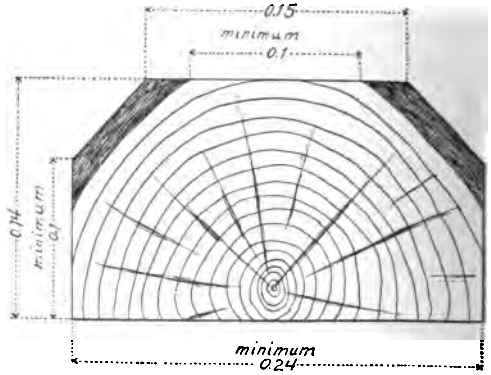

FIG. 5.—Standard tie, Bavarian state railways, suggested for use in the United States. (Measurements given are in fractions of meter.)

bearing surface at the base, thereby making the tie more stable, but would also permit of laying fewer ties per mile. (See fig. 6.)

It has been admitted that with the increased stiffness of the rail it might be possible to increase the spacing between the centers of bearing of neighboring ties. If this is true, ties such as the one indicated in fig. 5, with a top bearing surface of 6 inches and a base of 12 inches, could be spaced so that the distance between the bases of two neighboring ties would be the same as for a 7 by 9 inch tie. This would, of course, increase the distance between the bearing centers on the top of the ties (fig. 6). It is necessary to space ties so as to get the same number per rail length and avoid joints. This for a 7 by 9 inch tie is about 18 per 30-foot rail, with a space 11 inches wide between the two ties, or 20 inches between bearing centers. To avoid joints it will be necessary to space the new form so as to make either more or less than 11 inches between the extreme base points, and, in the comparison which follows, the spacing will be assumed as 10½ inches per 30-foot rail. (See fig. 6.) It is by no means meant to imply, however, that such would be the actual distance in practice. It is extremely probable that 10½ inches would be too close together to allow of a proper use of the shovel or other tool employed in tamping the tie, a point which deserves considerable attention when the question of tie spacing is being considered. It is extremely probable that the increased stiffness of the rail will permit of a spacing, with a tie of the form proposed, very much greater than is possible with the present tie.

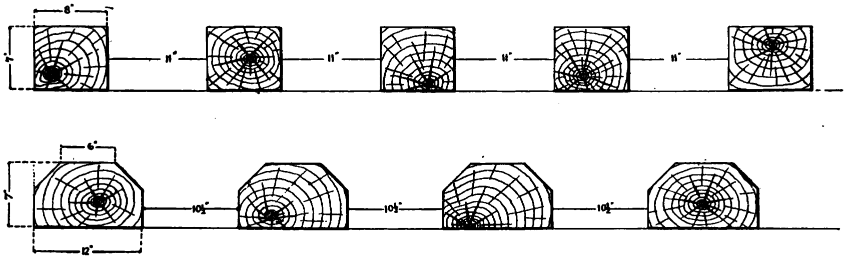

FIG. 6.—Manner of spacing 7 by 8 inch ties and half-round ties.

The comparative showing of rectangular 7 by 8 inch and 7 by 9 inch ties and of ties with a 6-inch top and 12-inch base, spaced respectively at 11 and 10½ inches, is as follows:

Items.	Rectangular tie.		New tie, 6-inch top 12-inch base.
	7 inches by 8 inches.	7 inches by 9 inches.	
Distance between bearing centers, on both top and base of tie	19 in	20 in	22.5 in.
Increase in distance between bearing centers by use of ties of the new form	3.5 in	2.5 in	
Total number of ties per mile	3,242	3,168	2,816
Number of ties per mile saved by use of new form	426	352	
Total linear bearing on ballast per mile	2,161 ft	2,376 ft	2,816 ft.
Bearing surface on ballast per mile, with 8-inch length	17,290 sq.ft	19,008 qs.ft	22,528 sq. ft.
Gain in bearing surface by use of tie of the new form	5,238 sq.ft.	3,520 sq. ft.	

According to this table the number of ties of the new form required per mile is 352 less than with the 7 by 9 inch tie, and 426 less than with the 7 by 8 inch tie, while the amount of bearing surface obtained is greater by 3,520 square feet than that obtained by the 7 by 9 inch tie—an increase in bearing surface of over one-sixth. At the same time there would seem at first sight to be a considerable saving from the smaller number of ties, but in reality there is little difference in expense because of the larger number of feet, board measure, in the new tie.

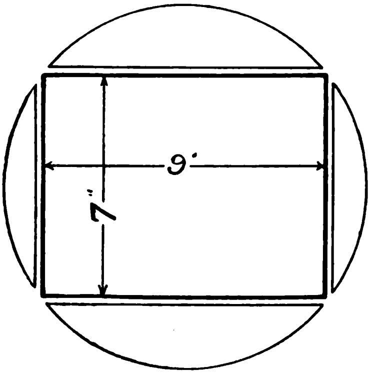

FIG. 7.—Manner of making one 7 by 9 inch tie from a log 11½ inches in diameter.

Having shown that a tie with a smaller bearing surface at the top and a larger one at the base is a better one from a mechanical standpoint, it now becomes necessary to consider the changed tie form from a lumber standpoint. The question is, Will it be more economical to cut ties of the form just indicated than the present rectangular tie? It ought to be stated that the suggestion for the adoption of the form above specified is by no means meant to exclude the rectangular tie now used. Whenever it will pay to purchase square ties with a bearing surface of 10, 11, or 12 inches, such ties will serve for all practical purposes as well as the one in which the bearing surface has been reduced to 6 inches.

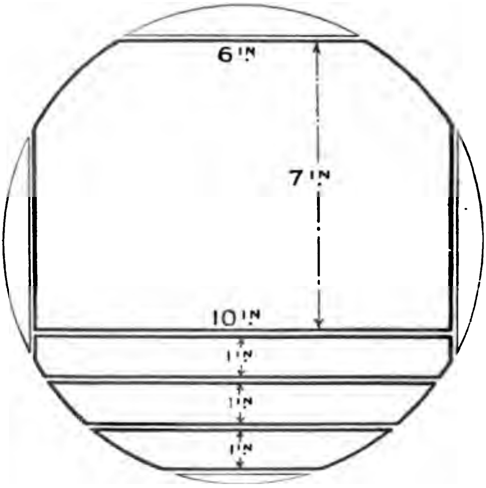

FIG. 8.—Manner of cutting one 6-inch face tie, with a 10-inch bearing surface and 7-inch thickness, and several boards from a log 11½ inches in diameter.

Ties are now being cut from trees of all diameters from 9 inches upward. If cut but one from a cross section, they are usually termed pole ties.

Most of these are rounded at the edge and squared on two sides (fig. 7), with a required bearing surface of 6 to 8 inches. Pole ties are now cut from trees as large as 17 inches in diameter. Most of them are hewn, and in the hewing much of the outer portion of the tree is wasted. In larger trees also a great deal of timber is wasted, even when ties are split in the most economical fashion. In the majority of instances no wane is admitted for a first-class tie, so that logs less than 10 inches in diameter will not make ties of this class. This means that a great many tops are now left in the woods because they are too small. By adopting the tie classification suggested above (and here again emphasis ought to be laid upon the fact that ties cut according to this shape will all be treated) it will be possible to utilize a great many logs which now do not make ties, and also to cut a good many more ties out of the same amount of timber than under the present specifications. This will appear from the diagrams (figs. 8 to 12). Fig. 8 shows a tree 11½ inches in diameter. Such a tree will make one 7 by 9 inch tie, or it will make a tie with a 6-inch bearing surface, 7 inches thick, and a 10-inch base, and a number of boards in addition, as shown in fig. 9. A log 15½ inches in diameter (fig. 10) will make only one 7 by 9 inch tie, but it will make two of the suggested form (fig. 5), while from a log 19.8 inches in diameter, which will make but two 7 by 9 inch ties, three ties, two 7 by 9 inches and one of the suggested form, can be cut (fig. 11).

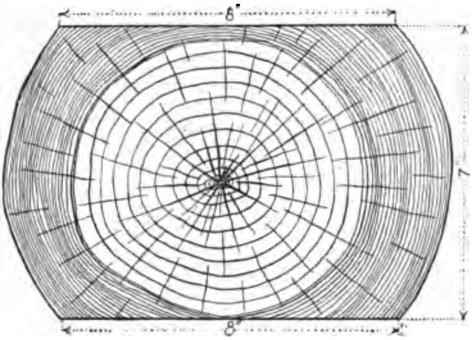

FIG. 9.—Pole tie.

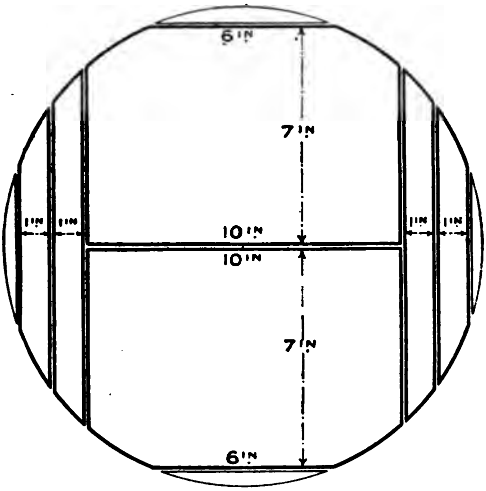

FIG. 10.—Manner of cutting two ties, with 6-inch face 7-inch thickness, and 10-inch base, as well as several boards, from a log 15½ inches in diameter.

The cutting of ties of this new form will be essentially a sawmill proposition. Where now there is a great deal of waste in hewing, if the log were sawed it would mean the obtaining of several boards on the side, as indicated in figs. 9 and 10. The number of boards to be sawed from a tree 16 inches in diameter, making two ties, will depend largely upon the value of the timber from which the ties are made. For instance, it will pay to make as many boards as possible out of a 16-inch, two-tie log of red oak or gum, while with timber like loblolly pine, the lumber of which has a low value, it will at present not pay to cut off many boards. In the case of such timber an extreme form of the half-round tie will be applicable (fig. 12).

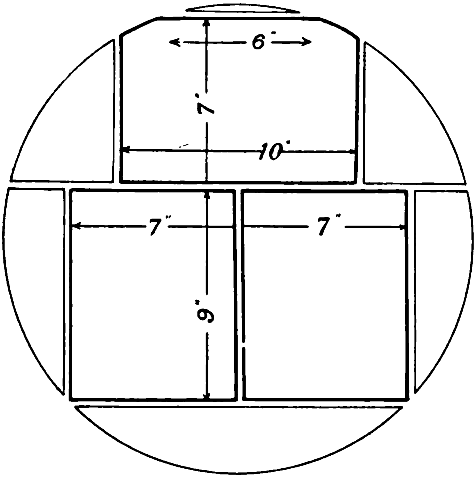

FIG. 11.—Manner of cutting ties from a log 20 inches in diameter.

The influence which the new tie form will have upon the size of trees cut for tie purposes ought to be a marked one. It certainly would discourage the cutting of pole ties to a very considerable extent. It would not pay to make a tie out of a small tree when by leaving it for a few years two ties could be made from the same tree. In other words, the present policy of cutting trees 11 or 12 inches in diameter would be found less profitable than cutting trees 16 or 17 inches in diameter. There is probably no other branch of the lumber industry in which so many small trees are annually destroyed and the possible regrowth of forests retarded to such an extent as in the manufacture of ties. The practice of sawing ties from logs is going to be more and more prevalent as the old feeling that a sawed tie is not worth having disappears. This feeling is already rapidly disappearing. It certainly will disappear entirely when railroad men realize that with a chemically treated tie it makes no difference whether it be sawed or hewn. With increasing permanency in the source of supply it will pay more and more to put up small sawmills, which will saw ties and such lumber as may incidentally come to them. This will be particularly true in regions where there are rapidly growing tree species, such, for instance, as loblolly pine. The cutting of these trees will, moreover, make possible the use of large quantities of tim-

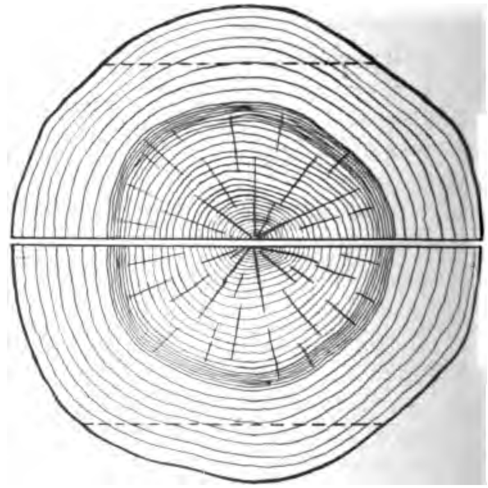

FIG. 12—Extreme form of half-round ties cut from a log of inferior lumber value.

ber which now is practically wasted and from which the lumberman has no return. This is particularly true of tops.

THE AMOUNT OF LUMBER IN THE PROPOSED TIE FORM.

It is interesting to know at this point to what extent the tie having a 6-inch bearing surface, a 7-inch thickness, and a 10-inch base compares in feet board measure with the ordinary 7 by 9 inch tie. The latter has 42 feet board measure against 41 feet board measure for the half-round tie.

The number of board feet in a tie 7 by 9 inches by 8 feet, when compared with rectangular and half-round ties of various dimensions, each sawed from the smallest log which will yield it, is as follows:

Board feet in ties of various sizes.

[All boards 1 inch thick and none less than 3 inches broad. One-eighth-inch saw kerf.]

Tie dimensions.	Volume.	Tie dimensions.	Volume.
	Board feet.		*Board feet.*
8 by 6 by 8 inches by 8 feet	32	6 by 7 by 12 inches by 8 feet	42
8 by 7 by 8 inches by 8 feet	37	6 by 6 by 10 inches by 8 feet	33
9 by 7 by 9 inches by 8 feet	42	6 by 6 by 11 inches by 8 feet	33
6 by 7 by 10 inches by 8 feet	41	6 by 6 by 12 inches by 8 feet	37
6 by 7 by 11 inches by 8 feet	42		

The manner in which these figures are arrived at will be made clear by consulting the diagrams (figs. 8 to 11). The ties are supposed to be scaled as one piece of dimension stuff as broad as the base of the tie and as thick as can be obtained without wane, and above that as inch boards. A tree 11½ inches in diameter will make one 7 by 9 inch tie measuring 42 board feet and 9 feet of boards, or a total of 51 feet cut from this log. The same log (fig. 9) will make one tie with a 6-inch top, 10-inch base, and 7 inches in thickness, measuring 41 feet board measure, and, in addition, 13 feet board measure of boards, a total of 54 board feet for the log—a difference of 3 board feet in favor of the half-round tie.

Fig. 10 shows the manner of sawing two half-round ties from a log 15.3 inches in diameter. Such a log will make only one 7 by 9 inch tie, but it will make two of the 6 by 7 by 10 inch ties. The 7 by 9 inch tie measures 42 board feet and the boards on the side 55 feet, a total of 97 board feet for a 15.3-inch log when sawed into a tie of the present standard shape. The same log will make two 6 by 7 by 10 inch ties equal to 84 feet board measure and boards equal to 17 feet board measure, a total of 101 feet board measure; that is, 4 board feet in favor of cutting the half-round ties. It must be remembered, however, that only in the rarest instances will it be possible to realize the full number of boards estimated for the ideal round tree; hence the difference between the two methods of cutting will probably be very small.

A complete discussion as to which tie form will prove the most economical of lumber can not be given at this time, since it will be necessary to determine this by an actual test in the sawmill. It may be of interest to add here several tables showing the number of ties and the number of boards which could theoretically be obtained from logs of various diameters. In the following tables the various standard forms now used are compared with the proposed forms. The dimensions given refer to the top width, the thickness, the bottom breadth, and the length; thus a tie with a top 8 inches wide, 6 inches thick, a base 8 inches in width, and 8 feet long is styled 8 by 6 by 8 inches by 8 feet.

Standard ties and board feet in logs of various diameters.

[All boards 1 inch thick and none less than 3 inches broad. One-eighth-inch saw kerf.]

TIES 8 BY 6 BY 8 INCHES BY 8 FEET.

Log diameter.	Volume.	Volume of ties.	Volume beside ties.	Total volume.
Inches.	*Ties.*	*Board feet.*	*Board feet.*	*Board feet.*
10	1	32	7	39
11	1	32	13	45
12	1	32	26	58
13	1	32	35	67
14	1	32	48	80
15	2	64	28	92
16	2	64	44	108
17	2	64	56	120
18	3	96	40	136
19	3	96	59	155
20	3	96	73	169
21	4	128	63	191
22	5	160	46	206
23	5	160	62	222
24	6	192	64	256

TIES 8 BY 7 BY 8 INCHES BY 8 FEET.

11	1	37	11	48
12	1	37	18	55
13	1	37	32	69
14	1	37	41	78
15	1	37	56	93
16	1	37	65	102
17	2	74	48	122
18	2	74	64	138
19	3	111	39	150
20	3	111	61	172
21	3	111	75	186
22	3	111	97	208
23	4	148	81	229
24	5	185	62	247

Standard ties and board feet in logs of various diameters—Continued.

TIES 9 BY 7 BY 9 INCHES BY 8 FEET.

Log diameter.	Volume.	Volume of ties.	Volume beside ties.	Total volume.
Inches.	*Ties.*	*Board feet.*	*Board feet.*	*Board feet.*
12	1	42	14	56
13	1	42	28	70
14	1	42	37	79
15	1	42	52	94
16	1	42	63	105
17	2	84	40	124
18	2	84	53	137
19	2	84	68	152
20	2	84	86	170
21	3	126	62	188
22	3	126	80	206
23	3	126	95	221
24	4	168	85	253

Ties of new form and board feet in logs of various diameters.

[All boards 1 inch thick, and none less than 3 inches broad. One-eighth-inch saw kerf.]

TIES 6 BY 7 BY 10 INCHES BY 8 FEET.

Log diameter.	Volume.	Volume of ties.	Volume beside ties.	Total volume.
Inches.	*Ties.*	*Board feet.*	*Board feet.*	*Board feet.*
12	1	41	16	57
13	1	42	29	71
14	1	41	38	79
15	1	42	49	91
16	2	83	21	104
17	2	86	32	118
18	2	86	50	136
19	2	86	64	150
20	3	122	40	162
21	3	133	54	187
22	3	132	75	207
23	3	133	96	229
24	3	132	115	247

TIES 6 BY 7 BY 11 INCHES BY 8 FEET.

12	1	42	16	58
13	1	43	25	68
14	1	41	37	78
15	1	42	49	91
16	2	92	17	109
17	2	96	27	123
18	2	96	40	136
19	2	97	59	156
20	3	138	32	170
21	3	145	42	187
22	3	150	63	213
23	3	150	86	236
24	3	150	104	254

Ties of new form and board feet in logs of various diameters—Continued.

TIES 6 BY 7 BY 12 INCHES BY 8 FEET.

Log diameter.	Volume.	Volume of ties.	Volume beside ties.	Total volume.
Inches.	*Ties.*	*Broad feet.*	*Broad feet.*	*Broad feet.*
13	1	42	25	67
14	1	46	34	80
15	1	46	45	91
16	2	100	8	108
17	2	112	17	129
18	2	104	32	136
19	2	112	40	152
20	3	125	28	153
21	3	142	33	195
22	3	162	52	214
23	3	162	68	230
24	3	162	82	244

The tie form here suggested is by no means new. Ties of this character have for many years been in use on the European railways. The manner in which the German lumbermen cut ties is illustrated in figs. 13–21. Fig. 53, which pictures a piece of Prussian track in process of construction, shows how these ties are laid in the track in relation to the tie-plates. In figs. 22 and 23 (p. 28) are shown two end views of ties used in Europe at present: fig. 22 represents the standard ties of Baltic pine used by the Prussian railways; fig. 23 shows the standard ties of beech and oak used by the French Eastern Railway. It will be noted that all of these conform more or less nearly to the type indicated above.

A good statement of a successful method of cutting ties from logs in this shape was obtained during the past summer from the Bavarian Government. The Bavarian state railways operate their own sawmill for the production of ties. The mill is located at Kirchseeon, near Munich, and is under the supervision of the superintendent of the treating plant. The Government buys logs of one and two tie lengths from the foresters, and saws them in the mill, primarily for ties, and incidentally for such small stuff as will utilize the otherwise waste portions of the logs. Only two sizes of ties are cut at this mill: Class 1, 16 by 26 cm. by 2.7 m. (6.3 by 10.2 inches by 8.9 feet) and class 2, 15 by 25 cm. by 2.5 m. (5.9 by 9.8 inches by 8.2 feet). The following statement of operations for 1902 was kindly furnished by the superintendent of the treating plant:

Quantity of pine logs bought (2,154,276 cubic feet) ....cubic meters..	61,000
Number of ties cut out of this timber, two sizes, 26 cm. by 16 cm. by 2.7 m. (10.2 by 6.3 inches by 8.9 feet) and 25 cm. by 15 cm. by 2.5 m. (9.8 by 5.9 inches by 8.2 feet)..........	305,000
Price paid for the wood ($294,168) ....marks..	1,236,000
Price obtained for boards, beams, lath, firewood, etc. ($79,968)....do....	336,000
Total cost of ties ($214,200)..........do....	900,000
Cost per tie (70 cents)..........do....	2.95

Figs. 13–21 illustrate the manner of sawing logs at the Kirchseeon plant. The Bavarian Government is well satisfied with the investment made in the sawmill, and believes that it thus obtains its ties cheaper than in the open market.

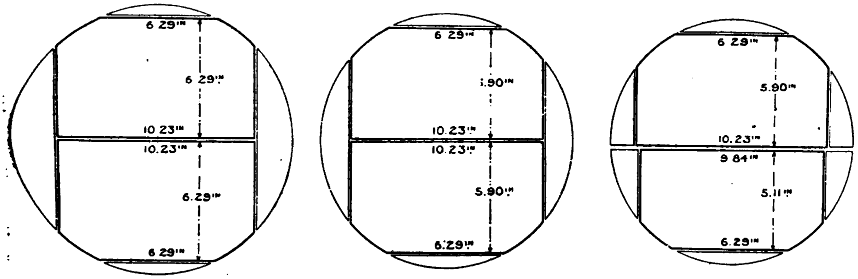

Fig. 13. Fig. 14. Fig. 15.

LOG DIAMETER 14.17 INCHES LOG DIAMETER 13.38 INCHES. LOG DIAMETER 12.99 INCHES.

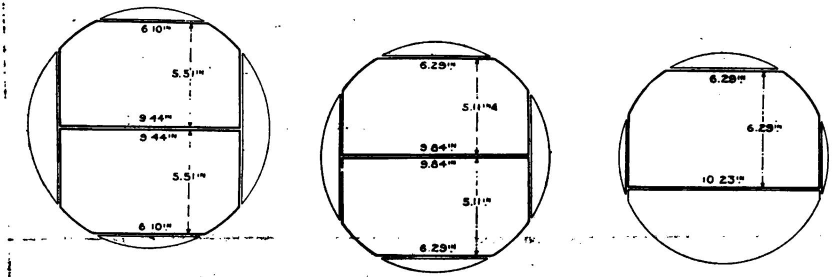

Fig. 16. Fig. 17. Fig. 18.

LOG DIAMETER 12.59 INCHES. LOG DIAMETER 12.20 INCHES. LOG DIAMETER 11.02 INCHES.

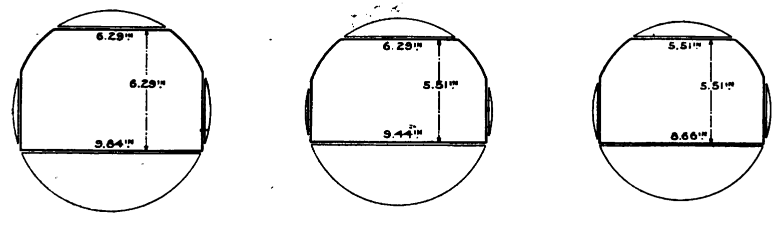

Fig. 19 Fig. 20. Fig. 21.

LOG DIAMETER 10.62 INCHES. LOG DIAMETER 9.84 INCHES. LOG DIAMETER 9.44 INCHES

FIGS. 13–21.—Manner of cutting ties practiced by timber contractors in Germany.

The ties used in Belgium are of the extreme half-round form. These ties are placed with the wide surface on the ballast, and a place is adzed in on the rounded surface big enough to hold the tie plate. This form of tie could be used advantageously with the cheaper kinds of timber in this country.

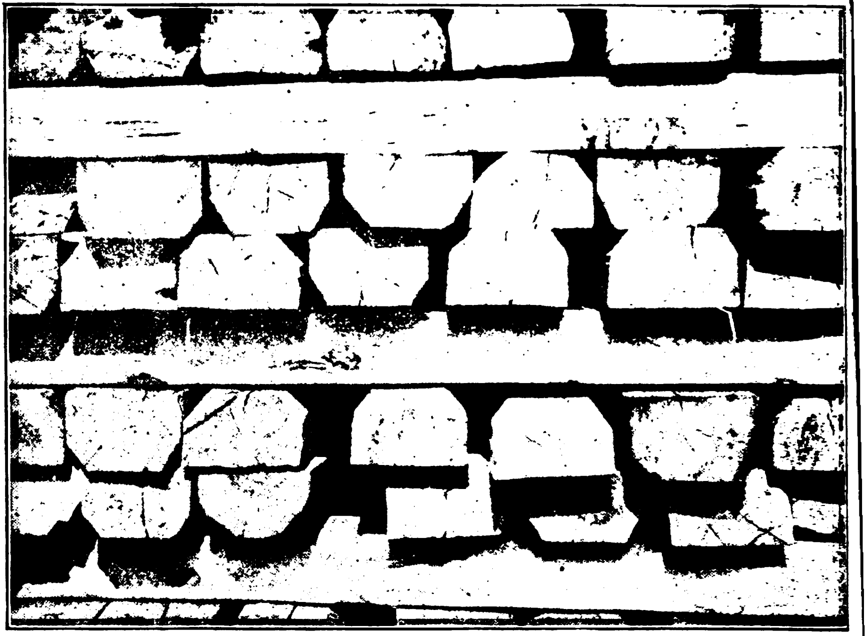

FIG. 22.—Standard Prussian ties of Baltic pine.

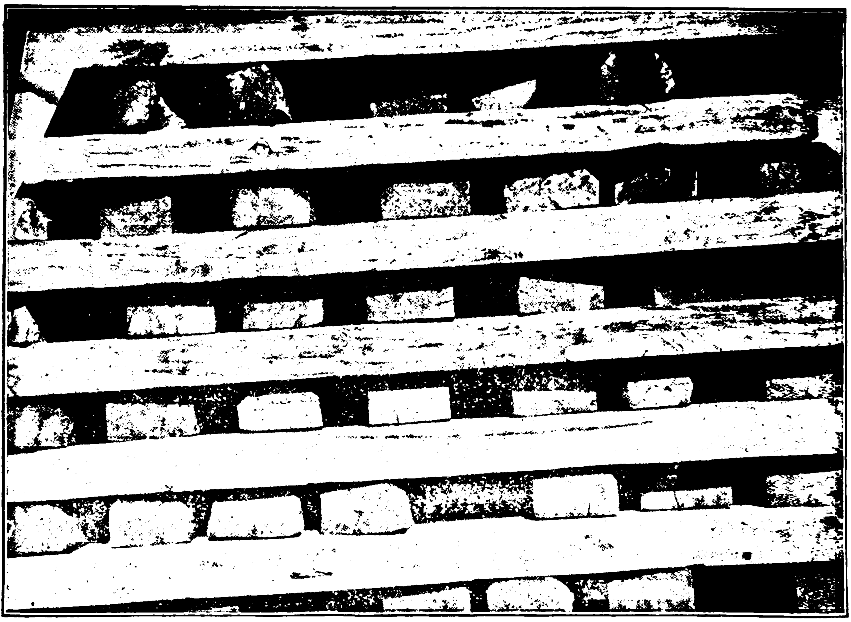

FIG. 23.—Standard oak and beech ties on the French Eastern Railway.

SUMMARY.

From the foregoing discussion we may make the following generalizations:

First. It is not desirable to continue the present method of classifying ties as first class, second class, etc., and culls. Instead, an alternative classification is proposed which substitutes a division into grades A, B, C, etc., each standing for a certain definite size. Such a classification would throw out the cull tie entirely.

Second. It is not desirable to decrease the number of ties of the present breadth now laid per rail length, for the reason that even with an increased stiffness of rail a reduction in the bearing surface on the ballast is not warranted, in view of the fact that a larger bearing surface on the ballast is continually being sought for. In this connection it must be remembered that closer spacing of ties will not be possible, since a certain minimum space must be maintained to permit proper track work. In other words, increasing the breadth of the tie will necessarily mean a reduction in number per rail length.

Third. Triangular ties are not desirable and ought not to be used, because they give less bearing surface on the ballast rather than more.

Fourth. Assuming that tie-plates are to be used on treated timbers of inferior grade, it is a waste of timber to require an 8-inch top bearing surface. It is therefore proposed that the present requirement be modified so as to admit timbers having a minimum of 6-inch top bearing surface. At the same time it is proposed that the bearing surface on the ballast be increased above 9 inches to such an extent as may prove advantageous, depending upon the class of timber from which the ties are made. This would make a "half-round tie" (fig. 5) of the following dimensions: Top bearing surface, minimum breadth, 6 inches; bearing surface on the ballast, 10–12 inches; thickness, 7 inches; length, 8 feet or more.

Fifth. The half-round tie is advantageous from a mechanical standpoint, because it gives greater bearing surface per mile and a correspondingly more stable track when spaced at approximately the same distance now used with 7 by 9 inch ties.

Sixth. The half-round tie is good for the lumberman, because in numerous instances it will make two ties where it would have been possible to make only one of the rectangular form.

Seventh. The half-round tie is good for the forest, because it will encourage the cutting of large trees and the saving of small ones and, further, will prevent the waste due to leaving many tops in the woods.

Eighth. Taking all these matters into consideration, it would appear that the half-round tie is worthy of trial. Experiments are now under way to test the practicability of sawing large numbers of these ties.

These experiments are being made in cooperation with the New York Central and Hudson River Railroad in the Adirondacks, with beech and birch, with the Santa Fé Railroad in Texas and Arizona with various pines, and with the St. Louis and San Francisco Railroad in Missouri and Arkansas and the Northern Pacific Railway in Montana and Washington with red fir and lodgepole pine.

RAIL FASTENINGS.

TREATED TIES REQUIRE PROTECTION AGAINST WEAR.

The rapid introduction of chemically treated softer timbers for ties has raised certain new questions of track construction and maintenance. One of the most important of these is concerned with the rapidity with which the treated ties have been wearing out under the rail. The rapidity of wear astonished many engineers, not only in the case of ties on which the rail rested directly, but also in that of treated ties on which tie-plates were used. This wearing out shows itself with softer woods in a very much more striking way than with woods like white oak and longleaf pine, and its rapidity comes as a particularly disagreeable surprise to those who had expected that the chemical treatment of such timbers as hemlock, western yellow pine, loblolly pine, etc., would make the inferior timbers serviceable in all respects.

The deterioration of ties is due to two causes: Wear because of mechanical abrasion, and decay. By treatment (with the possible exception of one or two kinds) decay only is arrested. In other words, the chemical treatment of wood protects it against decay, but not necessarily against mechanical abrasion. This fact does not seem to be generally recognized, and great emphasis should be placed upon it. It is easy to foresee a decided revulsion against timber treatment, for the reason that too much will be expected of it, and unless the causes for the removal of ties from the track are carefully studied, the blame for failure is sure to rest upon the treatment.

It can not be too strongly urged at this time that the use of inferior woods means not only a question of chemical preservation, but also a possible change in those mechanical arrangements which bring about wear. Cases of dissatisfaction with the inferior timbers are brought to light more frequently every day. This dissatisfaction has in some cases led to conferences called for the object of determining whether it would not be better to abandon the use of inferior woods for ties. On the other hand, it is pointed out that the largely decreased supply of high-grade timbers and their great expense, due to the demand upon these sources of supply for other purposes, have made it increasingly difficult for railroad companies to obtain any but the inferior woods. In view of this fact, the wiser attitude to take is one

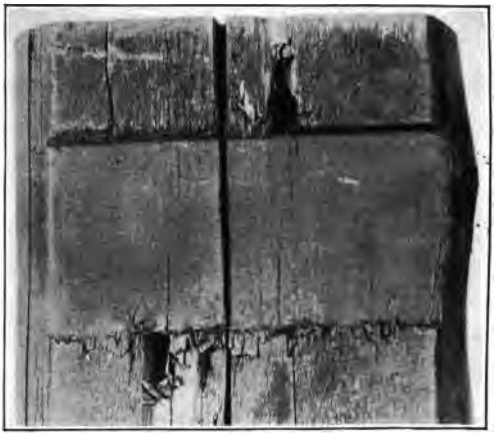

FIG. 1.—TIE AFTER ONE YEAR'S SERVICE IN THE TRACK.

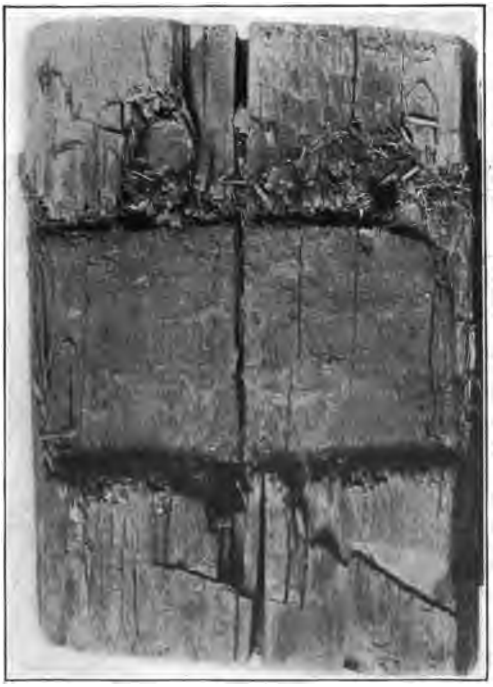

FIG. 2.—BADLY WORN TIE, TWO YEARS IN THE TRACK.

LODGEPOLE PINE TIES, TREATED WITH ZINC CHLORID, SHOWING WEAR UNDER THE RAIL.

looking toward investigations of how to overcome existing defects rather than one of condemnation of any particular timber. It is a question nowadays of what timbers railroads can get, not of what they want.

That wear is a very serious defect in the case of at least some of the softer timbers under present methods of use, the examples presented in Pls. I, II, and III plainly indicate. On Pl. I two photographs are reproduced, showing lodgepole pine ties in various stages of wear under the rail without tie-plates. Fig. 1 shows a tie which has been in service about a year; fig. 2 is a view of a similar tie which has been in service about two years. It will be noted that the wood around the spike holes has worn out, and that the fibers under the rail have been severely cut and bruised. On Pl. II, fig. 1, is represented a western yellow pine tie in Wyoming, cut to show the effect of driving spikes into these soft woods; fig. 2 shows a loblolly pine tie from Texas treated with zinc chlorid, after four years' service. This illustration is worthy of particular attention. It will be noted that the body of the tie, seen at one side of the picture, is still perfectly sound, while the wood under the tie plate is completely crushed. The spikes have pulled, and the tie has been rendered practically useless for track service. This particular tie will be discussed more in detail below. Pl. III shows two sections of the same loblolly pine tie—fig. 1 of a section immediately under the rail and fig. 2 of one through the middle of the tie. It will be noted that under the rail the tie is badly decayed and worn, while the body of the tie is perfectly sound. The cracks are due to the drying out of the tie. Of treated loblolly ties now coming out of the track, by far the larger number are being removed because they are in the condition shown in Pl. III, fig. 1, and not because they are wholly decayed. These effects of wear are, of course, absolutely independent of any chemical treatment of the wood.

The subject of track fastenings is discussed in the remainder of this bulletin, because it is believed by the writer that only with very much modified systems of fastening, can ties of most of the softer woods be made to last sufficiently long to pay for the chemical treatment. In other words, it will not pay to wear out a tie before it rots out.

The following forms of fastenings will be considered: Spikes, screw-spikes, tie-plates, dowels.

SPIKES.

In this country the ordinary nail-spike is universally used for fastening a rail to a wooden tie. The functions of this spike are supposed to be, first, to hold the rail to the tie, and, second, to prevent the rail from spreading laterally. There has been a good deal of discussion as to which of these two functions of the spike is the more important.

Many engineers consider that holding the rail to the tie is a secondary function, and that the main function of the spike is to hold the rail against lateral displacement. We find it stated:

> The principal duty of the track spike is not adhesion to the tie, but to hold against lateral displacement—the tenacity with which the spike resists pulling from the tie is relatively of small importance. On tangents the duty required of the spikes is mainly to establish the alignment of the rails, and not so much to maintain it, for if such track be kept in fair service there is little or no tendency for the rails to spread, and the spike is not subjected to lateral pressure of any account. * * * So far as the safety of the track is concerned, under normal conditions it would not matter if two-thirds or three-fourths of the spikes on tangents were pulled from the tie.[a]

While this statement may hold for hardwood ties, where the wear action of the rail is small, it certainly will not hold for softwood ties. This will be discussed more in detail presently; here it need only be said that, in the opinion of the writer, for the softer timbers the function of holding a rail to the tie is quite as important as the function of preventing lateral displacement.

A number of objections have been made to the ordinary spike. These objections hold good for almost all the various forms, and it is therefore unnecessary to go into a discussion of them. The more important objections to the spike, and the reasons why it contributes to wearing out the tie prematurely, are:

First. In the softwood tie the spike does not hold with sufficient firmness to prevent undulations and creeping of the rail, which results in a more or less rapid wearing out of the tie.

Second. In driving the spike into the softer woods the fibers are broken to an unusual extent. (Pl. IV, fig. 1.) As a result they do not withstand the lateral pressure of the rail, and consequently the spike hole is rapidly increased to such an extent that the spike no longer holds. Water collects in the enlarged hole, and decay sets in. (See Pl. IV, fig. 2.)

Third. Whenever a spike becomes so loose that it no longer holds, it is pulled out and driven in at another point. This constant respiking rapidly ruins the tie.

It is worth while to discuss these objections in detail. First, as to the effect of rail motion under a moving train load. This motion is undulatory in character. Without going into details describing the various elements of this motion, it will be sufficient for the present purpose to note that one of its results is gradually to lift the spike out of the wood. The upward pull has to be repeated many times before any impression is made on the spike, but eventually the resistance of the wood fibers holding the spike in position is overcome, so that after six months the head of the spike will stand one-fourth inch or more above the rail flange.

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[a] W. M. Camp: Notes on Track, p. 978, Chicago, 1903.

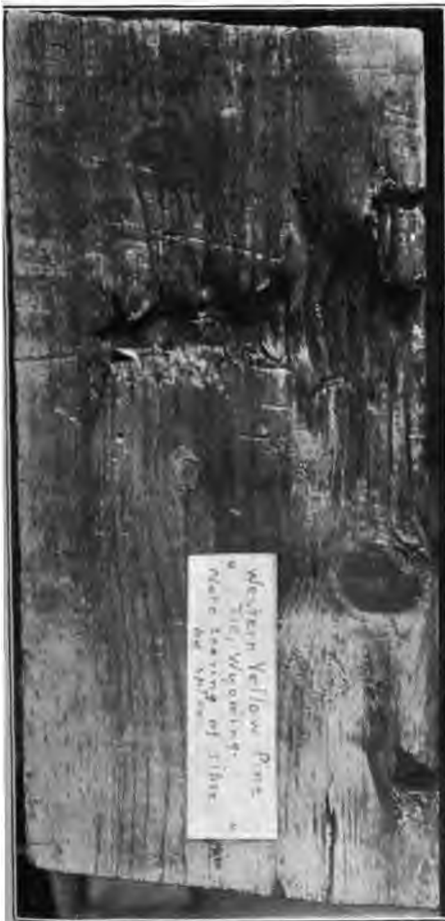

FIG. 1.—LONGITUDINAL SECTION OF WESTERN YELLOW PINE TIE AFTER SEVERAL YEARS' WEAR.

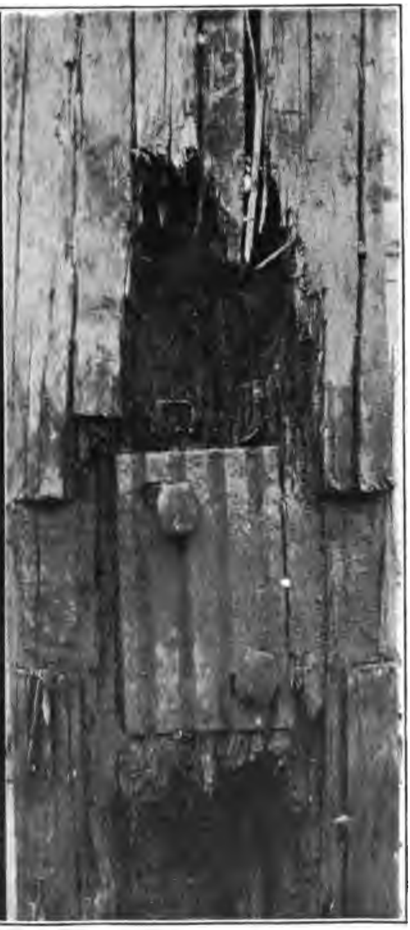

FIG. 2.—LOBLOLLY PINE TIE TREATED WITH ZINC CHLORID, AFTER FOUR YEARS' SERVICE IN TEXAS, SHOWING DESTRUCTION OF WOOD BY TIE-PLATES AND SPIKES.

Another effect of the wave motion of the rail upon the tie is to saw out the wood fibers immediately under the rail. The sawing is at first slight, but increases rapidly as the spike is pulled and after a few fibers have been broken. This is well illustrated by Pl. I, figs. 1 and 2. It will be seen that this sawing is at first in the nature of a compression, breaking the fibers in some instances, as shown particularly near the top of fig. 1, and in other cases completely sawing through the fibers, as shown in the lower left-hand corner of fig. 1. After long-continued action of the rail it may wear away enough of the tie to be embedded in it for a half inch or more. (See Pl. I, fig. 2.) The extent of wear will depend a great deal upon the wood and the character of the rail. A recent case cited in a paper by Dr. P. H. Dudley may be referred to. Doctor Dudley[a] shows figures of—

> A number of yellow pine cross-ties which had been in use on the New York Central and Hudson River Railroad five years under an 80-pound rail, and then seven years under a 100-pound rail. * * * Under the 80-pound rail they abraded only one-eighth inch to three-sixteenths inch in depth under the rail seats. Under the 100-pound seats the wood abraded only one-sixth inch to one-eighth inch in depth. * * * The important advantage of the stiffer rails is that they distribute the wheel loads to a longer portion of the track than is possible with the lighter rails. * * * They prevent the concentration of each wheel load over the cross-tie, which destroys the rail seat. The rapid introduction of stiff rails into the railroads of the United States at the present time will have much to do with checking the destruction of the cross-ties by the cutting of rail seats, so that the objection due to the use of treated ties on account of mechanical abrasion under the rail seats is no longer valid.

The experience of the New York Central is with a comparatively hard timber, the longleaf or yellow pine, and it remains to be seen to what extent this will be true of the softer woods. But while exactly the same results may not follow, the stiffer rails are certain to wear out a tie less than the lighter rails, provided they are held firmly to the tie. It is believed that the extent of sawing is due as much to the number of impacts of the rail on the tie under the passing loads as to the weight of the load. It is the undulation back and forth of the rail that produces the sawing, and the more frequently the rail undulates the more the tie will be worn out.

It appears, therefore, that an ordinary spike does not hold the rail firmly to the tie, and consequently allows of a more or less rapid wearing out of the fibers immediately under the rail seat.

The second objection to the spike is the breaking of the fibers incident to driving it. There is no doubt but that driving a blunt point into a solid body of wood results in the breaking of a considerable number of fibers. The extent to which the fibers will be broken in wood of various species will depend largely upon its hardness and density. Wood like white oak will not suffer materially from the action of driving spikes, while softer woods, like loblolly pine, red oak, and mountain pine, are injured considerably. This is well shown in Pl. II, fig. 1, which gives the longitudinal view of a tie made out of western yellow pine in Wyoming. This picture shows in a striking manner how a spike, when driven into soft wood, destroys the fibers. The tie shown in this illustration had been in service some three years, as is evident by the extent to which the fibers have been broken away near the top. In going into the wood the spike pushes the broken fibers aside so that the ends in many instances come to rest pointing downward. (See also Pl. IV, fig. 1.) The tendency on the part of these broken fibers to straighten forms the largest factor in holding the spike in position. With the constant pull upward, and particularly with the lateral strain, active whenever a train is moving over the rail, the fibers are weakened, so that after a while they are not able to withstand the lateral pressure, and a widening out of the hole results. In this hole water collects and a center for decay-producing factors will be set up. In Pl. IV, fig. 2, decay is already evident. It is a matter of common experience that the point at which most ties begin to decay is at or near the spike hole, and in view of such conditions as are shown in Pl. II, fig. 1, and in Pl. IV, fig. 1, this is not at all surprising. Where the tie has been treated with a salt soluble in water, the wood around the spike will lose its salt very soon after the spike begins to enlarge the hole, as a result of which decay sets in with considerable rapidity. This is well shown in Pl. II, fig. 2, Pl. IV, fig. 1, and Pl. IV, fig. 2, where the wear of the spike, in addition to that caused by the tie-plate, has allowed the zinc chlorid to wash out of the tie, permitting decay to set in.

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[a] Proceedings of the New York R. R. Club, vol. 13, p. 218, 1903.

Attempts have been made to overcome the difficulty by boring holes of various forms. Camp states (Notes on Track, p. 982) that those who have had experience with spikes driven in bored holes recommend boring the hole one-sixteenth inch smaller in diameter than the thickness of the spike and not deeper than the length of the spike exclusive of the head and the portion tapered for the point.

The third objection to the ordinary spike is the necessity for frequent respiking. It has been indicated above that the length of time during which a spike will hold the rail to the tie and resist lateral pressure is liable to be very short with the soft woods. After several years the hole is widened to such an extent by the breaking of the surrounding fibers that the spike becomes loose and no longer holds. It is a common practice to-day in such cases to pull such a spike and to drive it into the tie at some distance from the original hole. The old hole is commonly plugged. Not infrequently spikes are driven two or three times within a short distance of the same point. This respiking is kept up until there is no more wood available at that particular rail bearing. The tie must then be removed from the track,

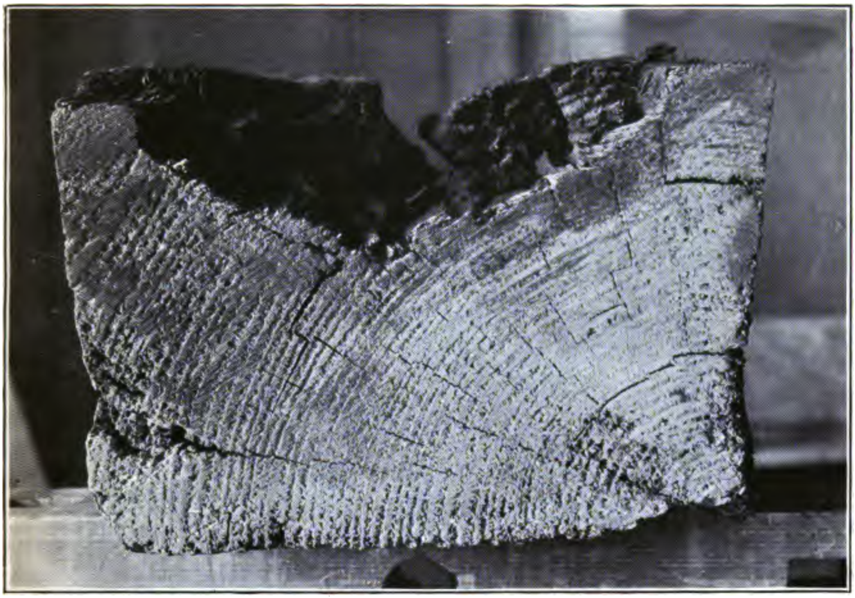

FIG. 1.—SECTION OF TIE UNDER RAIL BEARING, SHOWING WEAR AND DECAY.

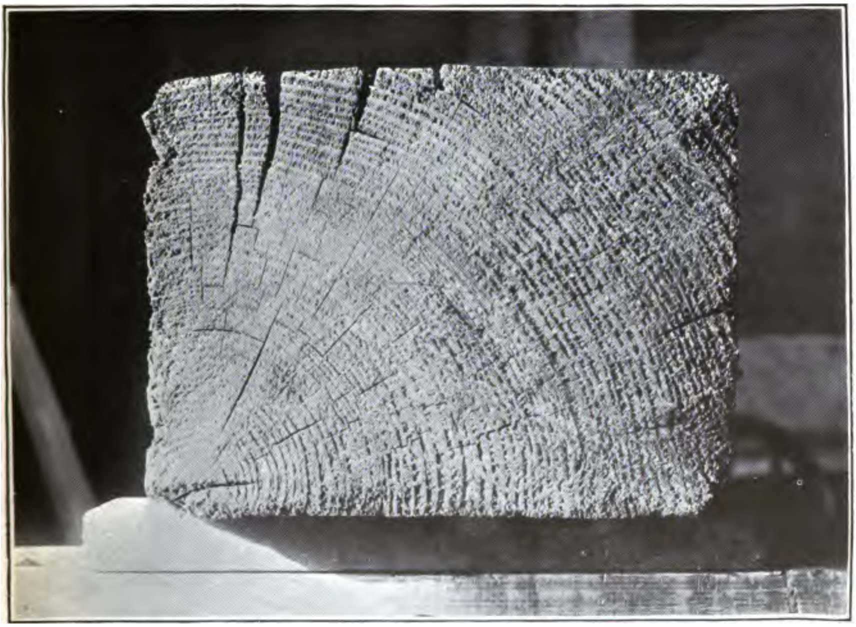

FIG. 2.—SECTION FROM MIDDLE OF ABOVE TIE, SHOWING ENTIRE SOUNDNESS.

LOBLOLLY PINE TIE TREATED WITH ZINC CHLORID, AFTER FOUR YEARS' SERVICE IN TEXAS.

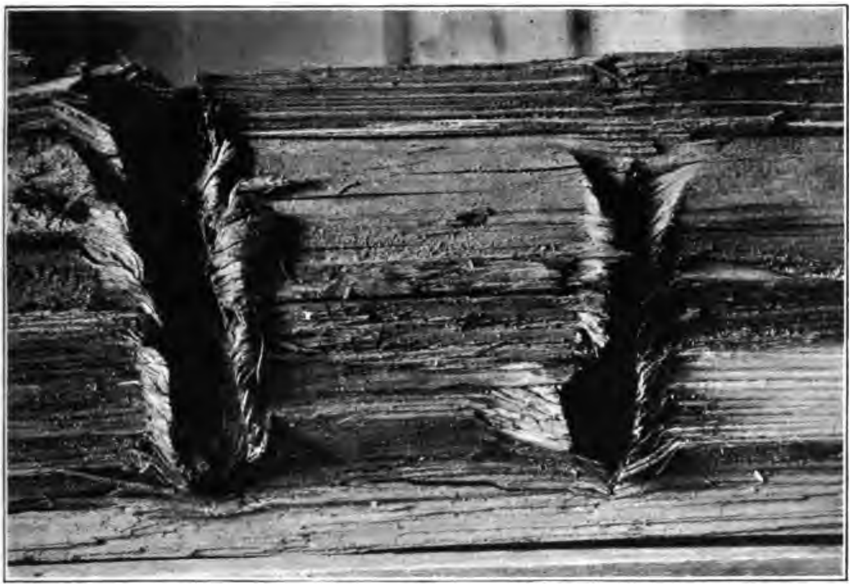

FIG. 1.—SHORTLEAF PINE TIE IN TEXAS, AFTER TWO YEARS' SERVICE, CUT THROUGH SPIKE HOLES, SHOWING THE MANNER IN WHICH THE WOOD IS BENT DOWN BY THE SPIKE ALL ALONG ITS COURSE.

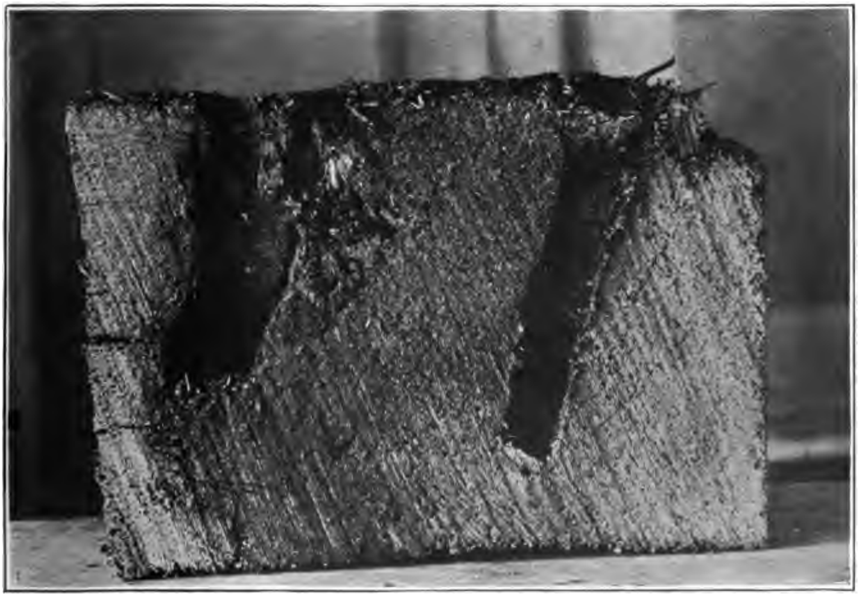

FIG. 2.—CROSS SECTION THROUGH THE SPIKE HOLES OF SHORTLEAF PINE TIE TREATED WITH ZINC CHLORID. TEXAS.

even though the greater part of it is still in good condition. Various devices have been employed to avoid this difficulty, particularly the well-known plug, by the use of which the holes are filled up so that the spike may be driven into the plug. This has been more or less successful. But the process known as "spiking a tie to death" is one only too familiar to almost every railroad man in this country. It is hardly necessary to say that the necessity for respiking is one of the most frequent causes of the rapid destruction of an otherwise sound piece of wood, and one which, in spite of the makeshift furnished by plugging, ought to be done away with wherever possible. This is especially true when we deal with treated ties, where any wounding of the timber is serious, since every new hole made gives an opportunity for the entrance of decay-producing factors which it is almost impossible to overcome. The matter might not be quite so bad if the operation as carried on in practice conformed to the ideal laid down by the instructions for driving spikes. It is a well-known fact, however, that the ordinary spike driving is a more or less haphazard affair, and that spikes go into the tie in every conceivable position, from the correct vertical position to angles of 45 degrees or more.

It appears, then, that while the ordinary spike may have served its purpose with the harder or more resistant woods, like oak, chestnut, and longleaf pine, it certainly has been found in the brief experience of its use in softer woods that it is a great source of trouble, and that it tends to wear out the tie rapidly. It now remains to be seen whether any of the other kinds of fastening are in any way superior to the ordinary spike.

SCREW-SPIKES.

Of several devices advocated as a track fastening, the most promising one is the screw-spike. The chief advantage which the screw-spike has over the ordinary spike is that, to a large extent, it is put in under circumstances which prevent the mechanical injury to the tie at the time, and when it is once put in it holds the rail to the tie so firmly that a large part of the wear is done away with. It is hardly necessary to explain in detail at this point why a screw is so much better able to withstand a vertical pull than a spike. When in position a screw firmly clamps the base of the rail against the wood, and thereby causes the rail and the tie to act as one body when a load is passing over the rail. While it is not possible to absolutely prevent the sawing action of the rail even when held with a screw-spike, nevertheless the sawing action is reduced to a minimum by the use of other devices, such as the tie-plates shown below. The necessity for a fastening such as the screw-spike gives has been realized for some years, and the sentiment is well expressed by Doctor Dudley[a] in the following words:

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[a] Proceedings New York R. R. Club, vol. 13, 1903, p. 218.

> We need better rail fastenings to screw the rails to the cross-ties than our ordinary spikes. This is for the purpose of reducing the looseness of the rail on the cross-tie. This will lessen the strain in the rails and also the injury to the permanent way. With the broad-top rails which are used in our tracks we make the wheel treads, as they pass over the rails, hold them in a vertical position, and do not depend as much upon the spike for the lateral stability as upon the proper distribution of the weights under the moving wheel loads. With the round-topped rails this statement does not apply, as in that case the lateral stability must be secured by the spike or chair. While the spike forms what may be termed a secure fastening, with our broad-topped rails it is not rigid. . . . The American theory and practice of securing the combined stability for the instant of the passage of the train is more by the construction of our locomotives and rolling stock than pertains elsewhere in the railroad world. With a more efficient rail fastening and treated cross-ties the combined stability between the locomotive and the permanent way could be increased.

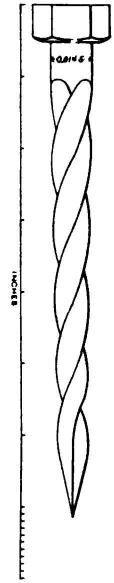

FIG. 24.—Simple form of screw-spike used in Baden previous to 1860.

It is here asserted that a more secure attachment of the rail to the tie would not only prevent wear of the tie and of the wood around the spike, but would also increase the general stability of the track. The passage of the load over rails securely fastened to the tie would cause the whole body of the track to move in unison, and the up-and-down motion of the rails would be reduced to a minimum.

In view of the general interest in fastenings, and in view of the tests now in progress with screw-spikes, it may be of interest to discuss at some length the past and present use of the screw-spike in other countries.

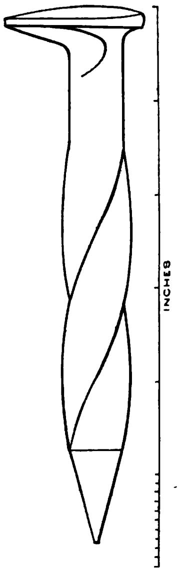

FIG. 25.—Spike recently patented which makes a half turn in being driven into the wood.

The question of the fixation of rails to wooden ties has occupied the attention of European engineers for many years. At the meeting of the International Railway Congress at St. Petersburg in 1885, and again at the meeting of the same congress at Paris in 1895, various forms of rail fastenings were discussed with a good deal of interest. The first use of the screw in its simplest form was probably in Germany, where an extremely simple nail modified so as to approach a screw form was used on the railways of the Grand Duchy of Baden before 1860 (fig. 24). This simple screw was driven into the tie with a sledge hammer, much as a nail-spike is driven into the wood. It is interesting to note in this connection that a similar form (fig. 25) has recently been contrived and patented in this country. It will be seen at it is based on almost the same idea as the old screw-nail used in

Baden. A modified lag screw used on the Kansas Pacific Railroad in 1870 is shown in fig. 26.

The greatest progress in the use of the screw-spike has without question been made by the French and Belgian railways. The French Northern and French Eastern and the Paris-Lyons-Mediterranean railways, as well as the Belgian roads, made tests with various forms of spikes as early as 1860. After 1863 the Paris-Lyons-Mediterranean Railway employed an iron screw-spike of 14 mm. (0.551 inch) diameter, shown in fig. 27. This form of spike had already been used to some extent in Germany. After 1863 the French road abandoned the screw-spike for an octagonal bolt for some years. In 1863 the French Northern and French Eastern roads, which had been using an ordinary nail spike which they found very defective, began using screw-spikes of the forms shown in figs. 28 and 29. These resemble the original screw-

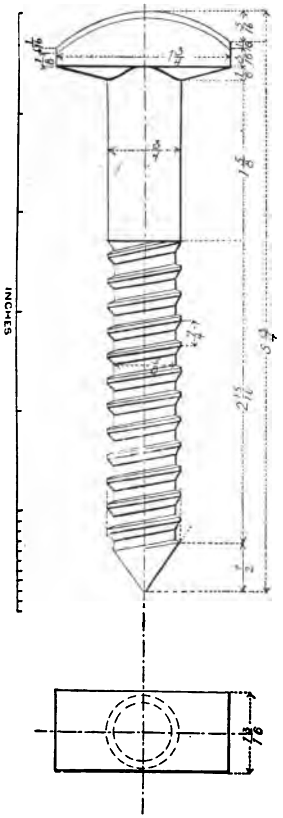

FIG. 26.—Modified lag screw used on Kansas Pacific Railroad in 1870.

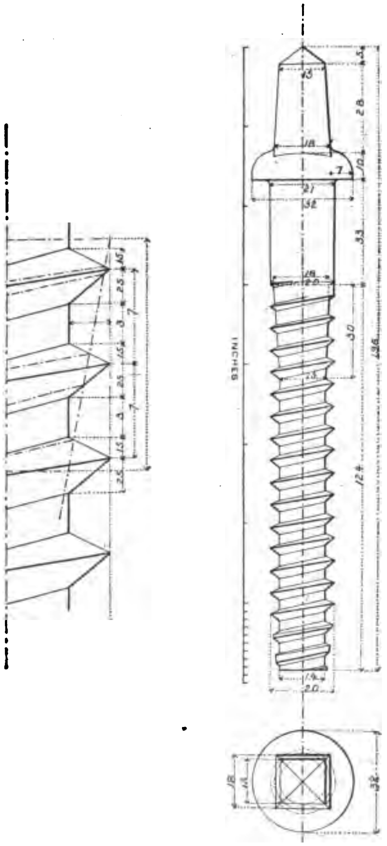

FIG. 27.—An iron screw-spike used by the Paris-Lyons-Mediterranean Railway in 1863.

spike used by the Paris-Lyons-Mediterranean Railway (fig. 27). In 1875 the latter road dropped the use of the bolt and adopted a screw-spike of the type shown in fig. 30, which was similar in many respects to the type of screw-spike used by the French Northern Railway (fig. 28), but which had the improvement of an increase in the pitch of the threads. It will be noted that the prism of wood between the two threads, which is the active part of the wood resisting the vertical pull, was 10 mm. (0.394 inch) in thickness in this new spike instead of 7 mm. (0.276 inch) as in the old French Northern type. Theoretically, therefore, the resistance of the new spike to the vertical pull should have been about double that of the old type with less injury to the fibers of the wood. About this time (1878), at the eighth reunion of the German Railway Union at Stuttgart, a report was made recommending the adoption of the screw-pike instead of the ordinary spike.

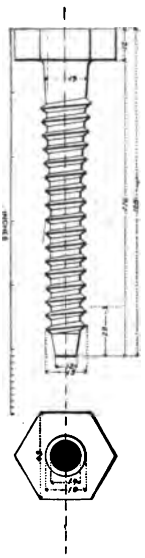

FIG. 28.—Screw-spike used by the French Northern Railway in 1863.

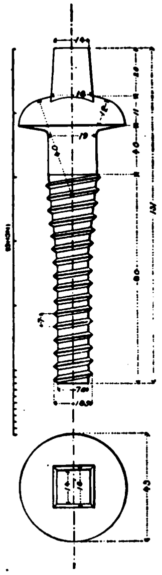

FIG. 29.—Screw-spike used by the French Eastern Railway in 1863.

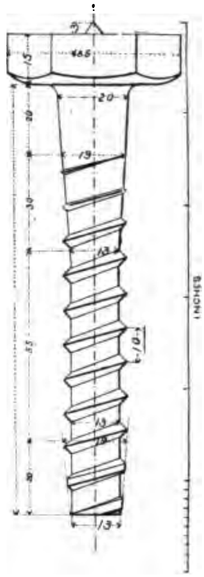

FIG. 30.—Screw-spike used by the Paris-Lyons-Mediterranean Railway in 1876.

The screw-spike adopted by the Paris-Lyons-Mediterranean Railway was at first made of iron rolled cold. About 1878 an attempt was made to roll the metal hot in appropriate molds. A serviceable spike was made, but it required particularly skilled labor, and too often the threads were defective. The great heat frequently burned and weakened the iron so that the heads broke off. When it became necessary to still further increase the solidity of the rail fastening, most of the

French roads increased the size of the screw. This was done almost simultaneously by the French Northern, Eastern, and the Paris-Lyons-Mediterranean companies. They all adopted the screw-spike 23 mm. (0.906 inch) in diameter, with a core of 17 mm. (0.669 inch) diameter instead of the core of 14 mm. (0.551 inch). Figs. 31 and 32 show the type used by the Eastern and Northern companies, and fig. 33 represents that used by the Belgian state railways. In 1881 the French Eastern adopted a round head for this screw-spike, and at the same time made it of steel rolled when hot. The same year the Paris-Lyons-Mediterranean Company adopted a screw-spike of the form shown in fig. 34. In 1889 further experiments were undertaken by this company to determine whether it would be possible to increase the pitch of the thread so as to facilitate its entrance into the wood without diminishing its resistance to a vertical pull. As a result of a series of tests the spike shown in fig. 35 was adopted. It has 9 spirals with a pitch of 12.5 mm. (0.492 inch). The height of the thread is 3 mm. (0.118 inch), as with the older types. This screw weighs about 0.415 kg. (0.915 pound).

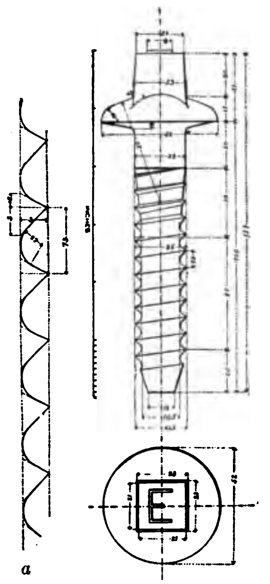

FIG. 31.—Screw-spike used by the French Eastern Railway in 1880.

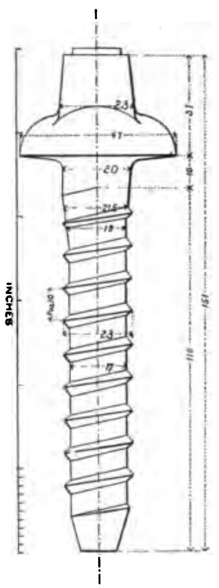

FIG. 32.—Screw-spike adopted by the French Northern Railway in 1880.

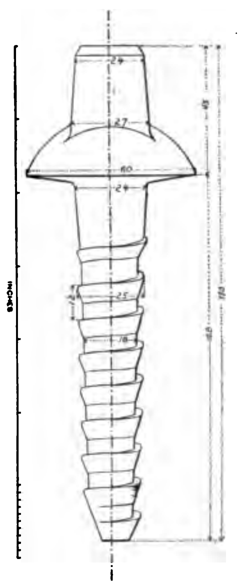

FIG. 33.—Screw-spike used by the Belgian railways in 1880.

> The conclusion arrived at by the French engineers is that the screw-spike of the type just described [fig. 35] insures the stability of the road and prolongs the durability of the rails and of the ties. It is a very striking fact, moreover, that it never occurs to the section-men at work on the track to use a sledge in driving the screw-spikes having a thread of this slight pitch. (Jules Michel—"La Question des Tirefonds"—Rev. Gen. d. Chemin de Fer et de Tramways, June, 1903.)

For a time a number of the French roads used a screw-spike such as the one shown in fig. 31, in which there was a sharp spiral, as indicated by the curves "a" at the left of the figure. This type of screw-spike is still in use in Austria (see fig. 36), but has been abandoned by the French lines because they found that the resistance offered by this type of spiral was nowhere nearly so great as that offered by the thread of the wider spiral in use to-day.

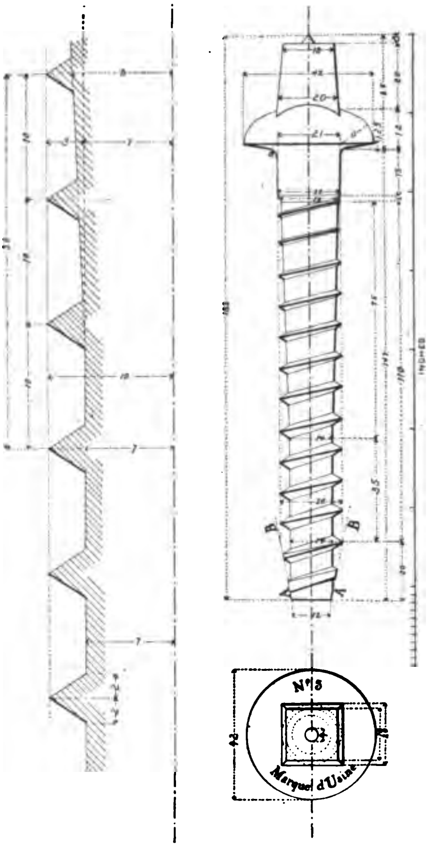

FIG. 34.—Screw-spike used by the Paris-Lyons-Mediterranean Railway in 1881.

The types of screw-spikes now used in various countries are shown in figs. 36 to 40. Fig. 36 represents the Austrian type, fig. 37 the German spike, fig. 38 the French Eastern, fig. 39 the Bavarian, and fig. 40 the Italian. The following figures from a paper by the maintenance of way engineer of the Paris-Lyons-Mediterranean Railway, M. Jules Michel, show why the screw of the present shape was employed by his company to the exclusion of the close-wound spiral. These figures summarize the results of experiments conducted at various times by the construction department of the Paris-Lyons-Mediterranean Company. The mathematical discussion of the subject which occupies the remainder of this section, extending to the bottom of p. 46, is a presentation of the points as developed in M. Michel's paper, and is virtually translated from it.

TABLE III.—*Force required to pull out a distance of 0.005 m. (0.197 inch), screw-spikes driven 0.015 m. (0.591 inch) into woods of different kinds.*

TIES TESTED BEFORE LAYING.

Date of experiment.	Diameter of hole in wood.		Diameter of screw-spike.		Pitch of thread.		Pull exerted.							
							Northern fir.		Pine.		Beech.		Oak.	
	Meter.	*Inch.*	*Meter.*	*Inch.*	*Meter.*	*Inch.*	*Kilos.*	*Pounds.*	*Kilos.*	*Pounds*	*Kilos.*	*Pounds.*	*Kilos.*	*Pounds.*
1875	0.015	0.591	0.020	0.787	0.010	0.394	2,600	5,732	....	....	4,300	9,479.9	4,500	9,920.8
1881	.015	.591	.020	.787	.010	.394	....	....	....	....	4,600	10,141.3	4,800	10,582.2
1889	.014	.551	.020	.787	.010	.394	....	....	....	....	....	....	5,250	11,574.3
	.014	.551	.020	.787	.0125	.492	....	....	....	....	....	....	5,825	12,841.9
	.014	.551	.020	.787	.0150	.591	....	....	....	....	....	....	5,650	12,456.1
	.017	.669	.020	.787	.0125	.492	....	....	....	....	....	....	5,600	12,345.9
1891	....	....	.020	.787	.0125	.492	3,465	7,639	5,160	11,375.8	....	....	....	....

TIES TESTED AFTER NINE YEARS' SERVICE.

Date of experiment.	Diameter of hole in wood.		Diameter of screw-spike.		Pitch of thread.		Northern fir.		Pine.		Beech.		Oak.	
	Meter.	*Inch.*	*Meter.*	*Inch.*	*Meter.*	*Inch.*	*Kilos.*	*Pounds.*	*Kilos.*	*Pounds*	*Kilos.*	*Pounds.*	*Kilos.*	*Pounds.*
1889	0.014	0.551	0.020	0.787	0.010	0.394	....	....	....	....	....	....	4,600	10,141.3
	.014	.551	.020	.787	.0125	.492	....	....	....	....	....	....	5,250	11,574.3

The average resistance of beech and oak to a vertical pull is approximately the same in the experiments of 1875 and in those of 1881. In 1889 the improvement in the method of manufacture of steel screw-spikes by the introduction of hot rolling, together with the lessened diameter of the hole in the wood, increased the resistance 15 per cent. The change of pitch from 0.010 m. (0.394 inch) to 0.0125 m. (0.492 inch) has further increased the resistance by about 10 per cent, until it has reached the equivalent of about 12,800 pounds in new oak wood and 11,600 pounds in wood having seen nine years' service, or an average of somewhere near 5,500 kg. (12,125 pounds) for ties in common use. But a further increase of pitch to 0.015 m. (0.591 inch) seems, on the contrary, to materially diminish the resistance. Finally, the screw-spike, 0.023 m. (0.906 inch) in diameter, with a thread pitch of 0.010 m. (0.394 inch) and a thread projection of 0.003 m. (0.118 inch), does not seem to give better results than the screw-spike of 0.020 m. (0.787 inch) with a pitch of 0.0125 m. (0.492 inch), whether used

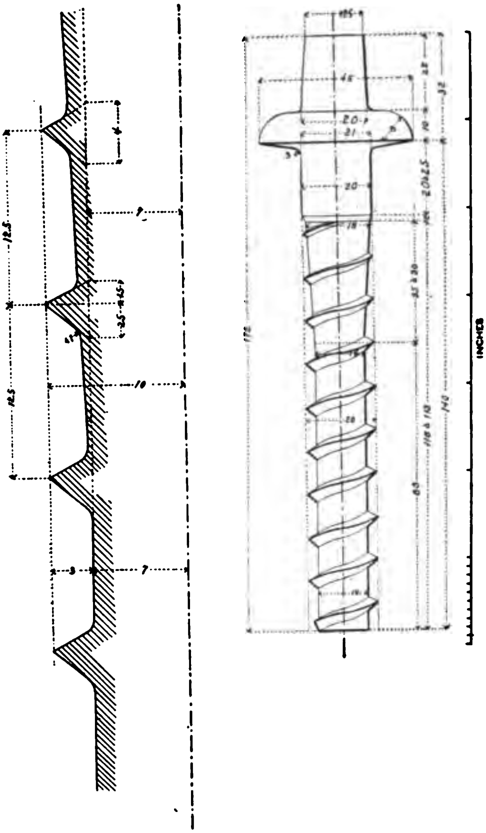

FIG. 35.—Screw-spike used by the Paris-Lyons-Mediterranean Railway in 1889.

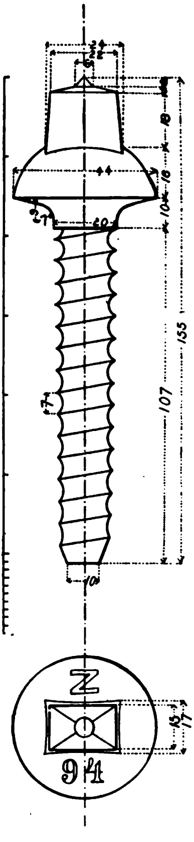

FIG. 36.—Screw-spike at present in use on the Imperial Ferdinand Northern Railway, of Austria.

in northern fir or in oak. The experiments reported in the preceding table show certain discrepancies which are not astonishing, for it is impossible to count upon the homogeneity of woods subjected to experiments. It was necessary to make a great number of tests to obtain averages, the value of which must even then be taken as only approximate.

Attention was also given to the shape of the section of the thread. This may be either in the form of an isosceles triangle or of a rectangular triangle, or of an intermediate form like that adopted by the Paris-Lyons-Mediterranean Company since 1863 (fig. 27).

Experiments conducted in 1889 have given the following results as to the pull necessary to draw 0.005 meter (0.197 inch) various types of screw-spikes in new oak and in ties which have been nine years in service:

TABLE IV.—*Force required to pull out a distance of 0.005 meter (0.197 inch) various types of screw-spikes.*

TIES TESTED BEFORE LAYING.

Diameter of screw spike.		Pitch of thread.		Pull exerted.			
				Isosceles thread.		Rectangular thread.	
Meter.	*Inch.*	*Meter.*	*Inch.*	*Kilos.*	*Pounds.*	*Kilos.*	*Pounds.*
0.020	0.787	0.010	0.394	5,300	11,681.20	5,460	12,033.84
.020	.787	.015	.591	5,650	12,452.60	5,675	12,507.70
.020	.787	.0125	.492	5,900	13,003.60	6,150	13,554.60
.023	.906	.0125	.492	6,088	13,417.95	6,088	13,417.95

TIES TESTED AFTER NINE YEARS' SERVICE.

Meter.	*Inch.*	*Meter.*	*Inch.*	*Kilos.*	*Pounds.*	*Kilos.*	*Pounds.*
0.020	0.787	0.010	0.394	4,650	10,248.80	4,500	9,918.00
.020	.787	.0125	.492	4,650	10,248.80	5,250	11,571.00
.0125	.492	.0125	.492	5,100	11,240.40	5,000	11,020.00

These tests do not show that preference should be given to the thread of rectangular form rather than to that of isosceles form, and since there was no reason for changing the Paris-Lyons-Mediterranean Company has retained the form which has been in use for a long time.

From the figures given in Table III we may determine what resistance the crushed oak fiber offers when compressed by the introduction of the threads of the screw-spike 0.020 meter (0.787 inch) in diameter. The resistance to a vertical pull, according to the tests of 1889, is 5,825 kilograms (12,841.9 pounds). This is contributed by the pressure of nine spirals, projecting 0.003 meter (0.118 inch), making in all a surface of 9 by 0.000160[a] square meter (0.001722 square foot), equal to 0.001440 square meter (0.01550 square foot), and by the friction of the core proper of 0.014 meter (0.551 inch) for a length equal to two-thirds of the total length of the spike, since the thread part occupies 0.004 meter (0.157 inch) of the pitch of 0.0125 meter (0.492 inch).

---

[a] Diam. screw=0.02 m.; diam. core=0.014 m. $\pi\ (R^2\text{-}r^2)=3.1416\ (.01^2\text{-}007^2)=.00016$.

Now a direct test shows for a smooth spike of 0.014 meter (0.551 inch) a resistance of 1,500 kilograms (3,307 pounds) to a vertical pull. It may be assumed, therefore, that the core of a screw-spike will, of itself, offer a resistance of 1,000 kilograms (2,205 pounds). The pressure on the surface of 0.001440 square meter (0.01550 square foot) will then be 4,828 kilograms (10,644 pounds), which gives a resistance of 335 kilograms (738.55 pounds) per square centimeter for new wood. For ties nine years in use the resistance would be only 4,250 kilograms (9,370 pounds), or 295 kilograms (650.36 pounds) per square centimeter.

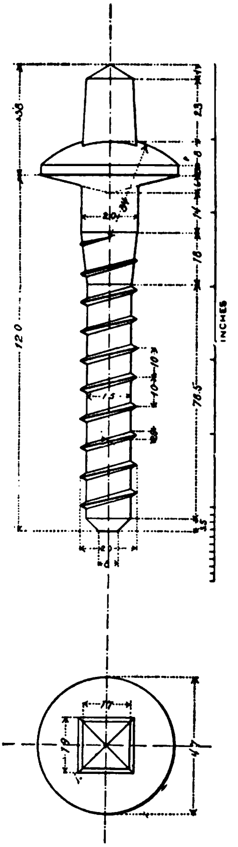

FIG. 37.—Screw-spike in use to-day on the Prussian Railway.

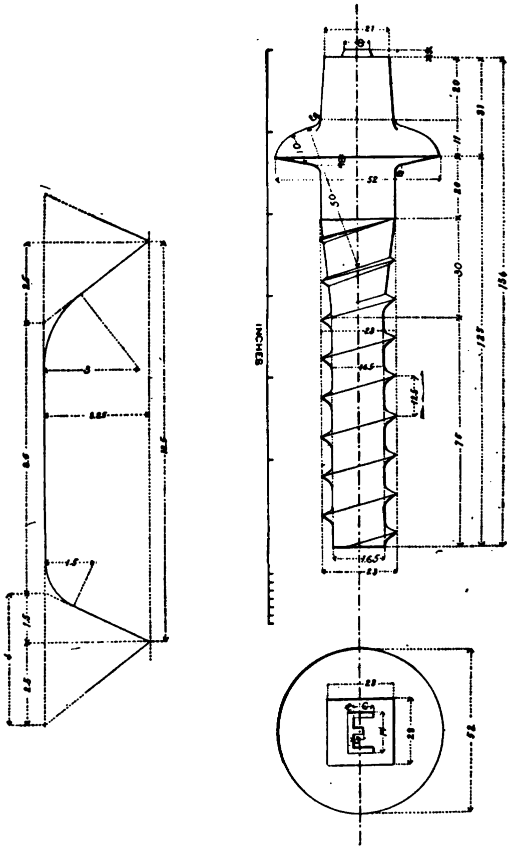

FIG. 38.—Screw-spike used to-day on the French Eastern Railway.

According to the tests described in the Railroad Review for July, 1884, the resistance of new oak to compression is 240 kilograms (529.11 pounds). The fiber of the wood compressed by the action of screwing the spike would, therefore, increase its resistance 40 per cent. The steel of which the screw-spikes are made has a tensile strength of

45 to 50 kilograms (99.21 to 110.23 pounds) per square millimeter, which is equivalent to 10½ times the resistance to the compression of wood in ties which have been in use several years.

Is there not reason to assume that the best type of screw-spike would be one which would engage the two substances in contact, viz. steel and wood, simultaneously to the limit of resistance of which they are capable? The Paris-Lyons-Mediterranean screw-spike does not correspond to this requirement, for the metallic core resists a strain of 7,000 to 8,000 kilograms (15,432 to 17,637 pounds), or an average of 7,500 kilograms (16,534.7 pounds) in new wood, and of 5,250 kilograms (11,574 pounds) in old wood, or an average of 5,500 kilograms (12,125 pounds).

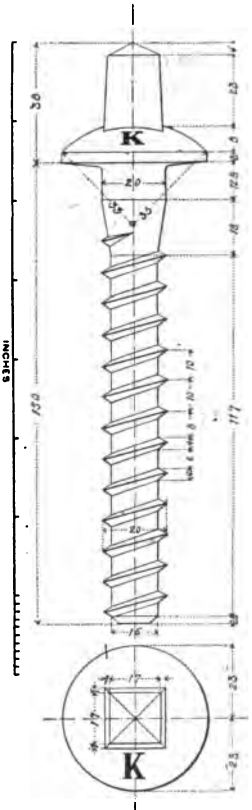

FIG. 39.—Screw-spike in use on the Bavarian state railways.

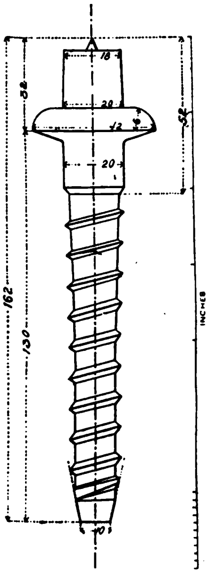

FIG. 40.—Screw-spike now in use on the Italian railways.

The thread surface should, therefore, be increased at the expense of the core of the screw-spike, or else the number of spirals should be increased by lengthening the threaded part. Assuming that we preserve a diameter of 0.020 meter (0.787 inch) in the shank, it would be necessary to give the core a diameter of 0.0128 meter, which would furnish a surface of 0.000129 square meter (0.001389 square foot) instead of 0.000154 square meter (0.001658 square foot) furnished by a core of 0.014 meter (0.551 inch). The tensile strength of the steel screw-spike would not be more than 6,250 kilograms (13,779 pounds). If the core has a diameter of 0.0128 meter (0.504 inch) the threads will form a projection on a plane perpendicular the axis of the screw-spike of 0.0036 meter (0.142 inch) on each side. Each convolution of the spiral will then have a surface of 0.001855 square meter (0.019968 square foot), and if there are 9 complete convolutions the total surface of the threads in contact with the wood will be 0.001669 square meter (0.017966 square foot) instead of 0.001440 square meter (0.01550 square foot), as in the present screw-spike, or an increase of 2.29 square centimeters (0.355 square inch).

The resistance to a vertical pull will increase, therefore, 2.29 by 335, or 767 kilograms (1,690.94 pounds). That is, instead of 5,500 kilograms (12,125 pounds), we would have a resistance of 6,267 kilograms (13,816.36 pounds), which is about equivalent to the tensile strength of the core of the screw-spike.

If instead of hard wood ties such as oak or beech, soft wood ties such as northern fir, were to be used, it would be necessary to still further increase the projection of the thread at the expense of the diameter of the core, taking as a basis the coefficient of resistance to compression for soft woods. It would, therefore, be desirable to increase a little the projection of the thread of the screw-spike used by the Paris-Lyons-Mediterranean Company. It is out of the question to consider lengthening the spikes, in view of the fact that the ties have practically, after a few years' service, and after the chipping to which they are subjected, a thickness of scarcely more than 0.120 meter.

The preceding suggestion will seem somewhat theoretical, but it may at least serve as a guide to engineers who are considering replacing the spikes now in use by a well-designed screw-spike in which the material may be used in a rational manner.

These researches are not without value, for if one refers to the tests of 1875 and 1889 on the vertical pull in northern fir and oak one sees the improvements introduced in the design of the screw-spike and in the mode of manufacture have increased the resistance about 30 per cent, or from 3,465 kilograms (7,636.86 pounds) to 4,500 kilograms (9,918 pounds) in the case of oak.

From the above, it is a reasonable conclusion that the proper device for fastening the flange of the rail upon the wooden ties *is a steel screw-spike, threaded hot, with a pitch of at least 0.012 meter (0.472 inch) for a shank with a diameter of 0.020 meter (0.787 inch) and with the length, diameter of core, and projection of thread calculated, respectively, to offer a resistance to a vertical pull, the nature of the ties being considered about equal to the resistance to rupture under tension of the core of the screw-spike.* Finally, this screw-spike must be driven into a hole previously bored with an auger having a diameter not appreciably greater than that of the core. This hole may be conveniently widened from 0.08 to 0.12 inch at the top to facilitate the entrance of the shank of the screw-spike in the wood, into which it penetrates from 0.010 meter (0.394 inch) to 0.01 meter (0.394 inch). The type of spike shown in figure 38 practically fulfills these conditions, and it is the one now being tested in this country.

TESTS OF THE COMPARATIVE PULLING STRENGTH OF COMMON SPIKES AND SCREW-SPIKES.

ACCOUNT OF TESTS.

The Bureau of Forestry has lately tested the pulling strength of spikes at its timber-testing station at Purdue University. A special holder was constructed, contrived to grip the heads of the spikes in a manner like the action of the rail, and to pull them from the tie in the direction of their length. The load at which the spikes pulled out from the ties was measured in pounds. Common spikes were driven into actual ties by an experienced track foreman to a depth of 5 inches, and then pulled out by a testing machine.

The screw-spikes were screwed into the same ties by hand, after a hole had been bored in the wood of a diameter equal to the diameter of the screw-spike at the root of the thread, namely, five-eighths of an inch. The load at which the screw-spikes pulled out was also measured on the testing machine.

MATERIAL.

The common spikes were 5½ inches long, nine-sixteenths by nine-sixteenths inch in cross section, and weighed 170 to the hundred pounds. The screw-spikes were machined spikes, 5½ inches long, with a diameter at root of thread of five-eighths inch. The size of the thread was one-eighth by seven thirty-seconds of an inch, and the pitch of the thread 2 inches; 85 spikes to the 100 pounds.

The tests were made on two seasoned chestnut and three oak ties, and one tie each of white oak, loblolly pine, and longleaf pine. Of the chestnut ties, No. 1 was perfectly sound. The other, No. 2, showed slight evidence of dry rot on the surface. The three oak ties had been in service from six months to one year. No. 1 was of good quality; No. 2 slightly rotten on the surface; No. 3 of good quality. The white oak was a piece 6 by 8 inches in cross section, of good quality and nearly dry. The loblolly pine was a piece 8 by 8 inches in cross section, dry and of good quality. The longleaf pine was 8 by 8 inches in cross section, nearly dry, and of good quality. The white oak, loblolly pine, and longleaf pine ties were procured in a lumber yard.

RESULT OF TESTS.

The force in pounds required to pull from the several ties the screw-spikes and common spikes was found in each case to be as indicated in the following table.

TABLE V.—*Result of tests.*

Kind of wood.	Force required to pull spike.	
	Screw-spike.	Common spike.
Chestnut:	*Pounds.*	*Pounds.*
No. 1	11,150	2,600
	10,950	3,220
	8,620	....
No. 2	7,470	3,250
	8,900	3,080
Average	9,418	2,980
Oak:		
No. 1	11,550	3,760
	11,100	5,300
	8,900	4,860
	8,940	3,490
	13,530	4,300
No. 2	12,300	....
	12,600	....
No. 3	11,000	....
Average	11,240	4,342
Longleaf pine	8,500	2,500
	11,440	2,000

Kind of wood.	Force required to pull spike.	
	Screw-spike.	Common spike.
	Pounds.	*Pounds.*
Longleaf pine	11,330	2,610
	8,820	2,790
	12,700	1,580
Average	10,558	2,296
White oak	11,050	6,160
	13,700	7,000
	13,670	6,780
	14,940	7,870
	11,770	6,940
Average	13,026	6,950
Loblolly pine	8,850	3,700
	6,500	3,320
	8,930	2,940
	9,100	3,690
	9,140	3,720
Average	8,504	3,474

Summary of averages.

Kind of wood.	Force required to pull spike.		Ratio of resistance of screw-spike to common spike.
	Screw-spike.	Common spike.	
	Pounds.	*Pounds.*	
Chestnut	9,418	2,980	3.10
Oak	11,240	4,342	2.60
Longleaf pine	10,558	2,296	4.63
White oak	13,026	6,950	1.87
Loblolly pine	8,504	3,474	2.45

Other tests made to determine the relation of the pulling strength of common spikes to the depth inserted in the wood showed that the pulling strength varied directly as the depth of insertion into the tie.

TESTS UNDER SIDE BLOW.

In order to determine what is the effect of a side blow such as comes on a spike from the rail in service, and what tends to spread the track, a short piece of 50-pound rail was spiked to a shortleaf pine tie by two spikes on opposite sides of the flange. The rail was then turned sidewise so as to receive on the inside the blow of a falling weight, and a 500-pound weight was dropped against the side of the rail head, thus tending to jerk the inside spike from the tie and produce a side pressure on the outside spike. A drop of 3 inches produced the following effects on the common spike:

Test No. 1.—First blow pulled inside spike 1 inch; second blow pulled inside spike far enough for the rail to drop out.

Test No. 2.—First blow pulled inside spike one-fourth of an inch; second blow pulled inside spike far enough for the rail to drop out.

Test No. 3.—First blow pulled inside spike one-half inch; second blow pulled the inside spike out far enough for the rail to drop out.

The same 500-pound weight was dropped 3 inches on the head of a rail secured to the tie by two screw-spikes in the manner related above. Seven blows of the hammer did not start the inside screw-spike perceptibly, but gradually bent the head of the screw-spike over until the rail came out. The outside spike was slightly bent after the test.

Similar drop tests were made to determine the effect of a blow similarly delivered on the pulling strength of the spikes. One blow of the hammer from 3 inches high delivered to the side of the rail head fastened with two common spikes pulled the inside spike out about one-half inch. The rail head was then removed, and the pulling resistance of the spikes was determined in the testing machine. The inside spike, which had been started one-half inch, pulled out at 3,250 pounds, and the outside spike at 4,870 pounds.

Three blows of the hammer from 3 inches high were delivered to the rail head fastened with screw-spikes. The resistance of the latter against pulling out was then 8,930 pounds for the inside spike, and 10,300 pounds for the outside.

As the pulling strength of the common spike when not subjected to side blows was 4,380 pounds, and that of the screw-spike was 9,360 pounds, it appears that the pulling strength of the inside spike was diminished in each case, and that of the outside spike was increased. The latter effect was due to the bending of the spike. The effect of a great number of blows would undoubtedly be to diminish the pulling strength of the common spike because of the gradual destruction of the ends of the fibers of the wood in the hole.

The above results show that under the action of a side blow, such as comes on a rail, a common spike is pulled out from a fourth to a half inch, while the screw-spike is not preceptibly started.

APPLICATION OF THE SCREW-SPIKE.

The screw-spike is now used on practically all of the Continental European railways in one form or another, either exclusively or in connection with bolts or ordinary spikes. The manner in which the screws are put into position differs only in unimportant details in various countries, and it will be sufficient to describe their manner of application for one. For this purpose the Eastern Railway of France is chosen as exemplifying a high type of work. The new ties are run through a machine at the treating plant before treatment. This machine adzes and bores holes into the tie at points as shown in fig. 41, *a* and *b*. These holes have the shape shown in fig. 44. The upper part of the hole is wider, to admit the upper portion of the screw-spike. The ties are then treated with creosote and shipped out upon the line. When a tie is ready to be laid, the screw-spike is dipped in tar oil (of which each section crew has a bucket on its car) or tar oil is poured into the hole, and it is placed in the hole, the larger opening at the top

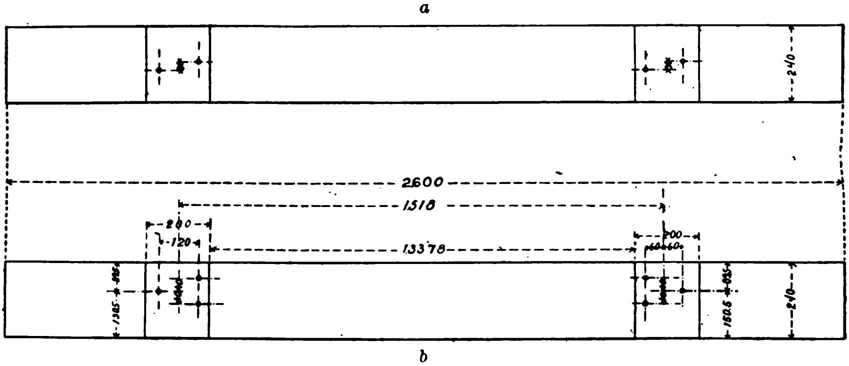

FIG. 41.—Manner of boring ties for screw-spikes used on the French Eastern Railway; *a*, joint tie; *b*, intermediate tie.

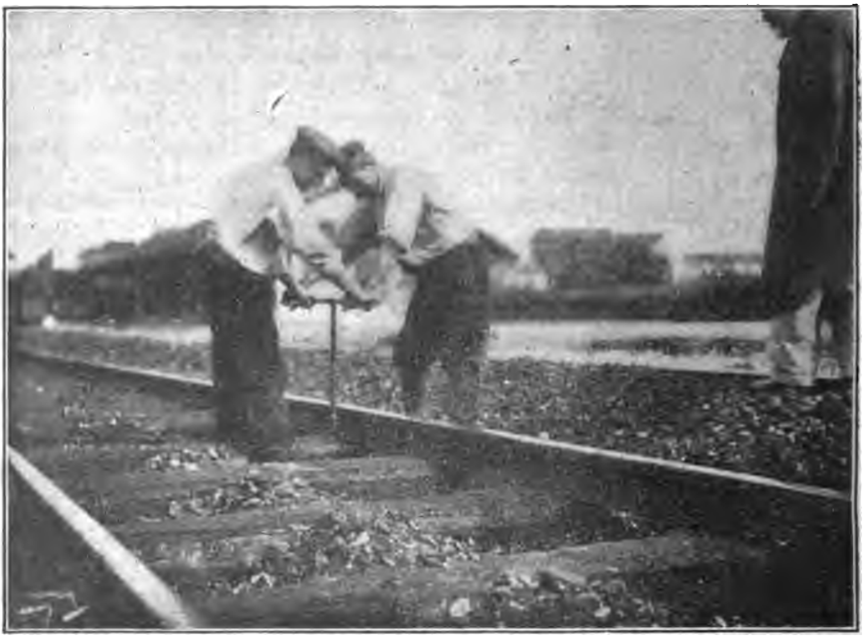

FIG. 42.—Ordinary method of inserting screw-spikes by means of a key operated by two men.

of this hole allowing the screw to drop into it so as to stand practically vertical. The key is then applied and the screw is turned in by two men, as shown in fig. 42. Great care is taken in making the final turn of the screw not to turn it too far, which would destroy the thread made in the wood. When it becomes necessary to unscrew any of the spikes, either for the purpose of moving the tie along to secure its proper spacing after several years' service or for the purpose of inserting a tie-plate, one or two turns are made so as to allow the rail to spring up, and when the tie has been moved, or the plate inserted, the screw is once more firmly bedded. The manner of inserting screws alternately, first one and then two per tie, is shown in fig. 43, and also in fig. 41, *b*. The two screws on the inside always correspond to one on the outside and vice versa, and if there are two screws on the inside of one rail there will be one screw on the inside of the other rail on the same tie. This may be seen in fig. 43, showing a French track with the ballast

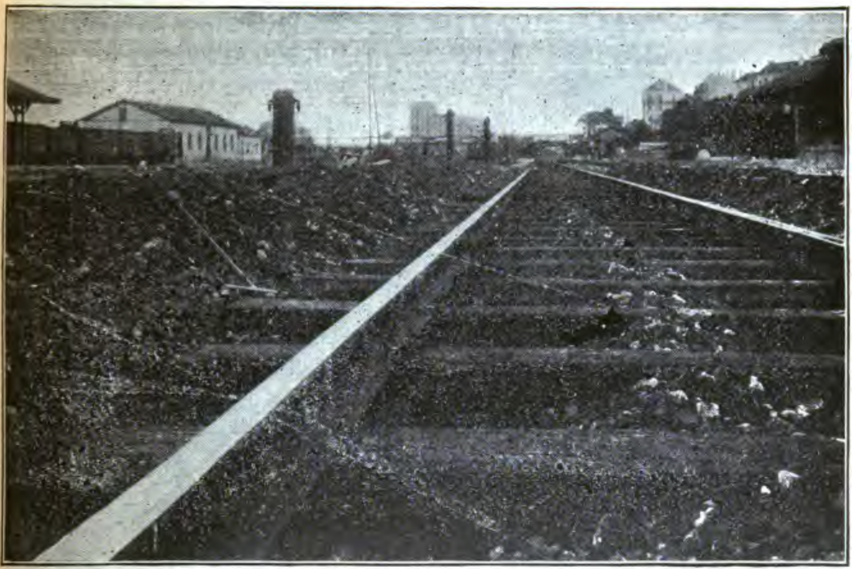

FIG. 43.—Manner in which the screw-spikes are used.

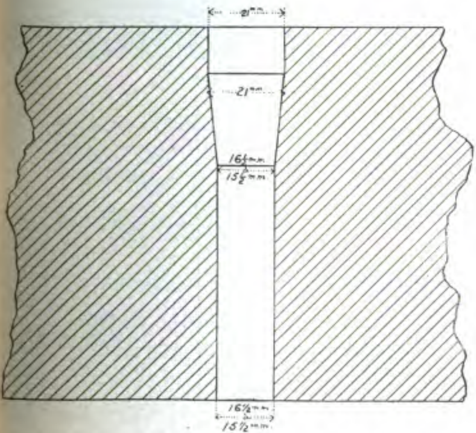

FIG. 44.—Shape of hole bored in the tie for the insertion of screw-spikes; French Eastern Railway.

partially removed. In rare instances screws are put in with a machine similar to the one shown in fig. 47, used principally for putting in dowels. Where long stretches of track are laid, such machines are very useful, but ordinarily for simple maintenance work the key is used, as shown in fig. 42. In a subsequent paragraph a hand machine for putting in these spikes is described in full. The relation of the screws to the rail is shown in fig. 45, which represents a section of the rail, a wooden tie-plate, and a tie as used on the French Eastern Railway.

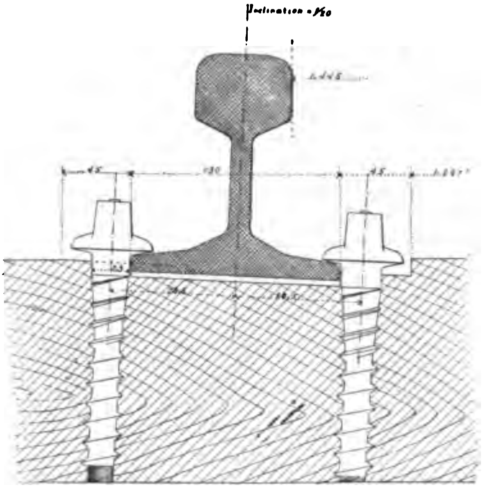

FIG. 45.—Section of rail and tie on the French Eastern Railway.

MAINTENANCE.

After the screw-spikes are once put in little work is required to keep them in proper condition. The wood is compressed by the threads as the screw enters, and the pressure of the core upon this highly compressed wood opposes a resistance to the loosening of the spike. However, after the spikes have been in position for a few weeks they have to be tightened. This is not because the screws have loosened, but because the ties, tie-plates, and rails have settled so as to come closer together because of the pressure of moving trains. After the screws have been tightened they remain so for long periods of time. Once a year the section crew goes over the track with great care, testing and tightening each screw, and, if any of the screws no longer hold, they are taken out. The hole is then filled with a plug, a new hole is made in the plug, into which tar oil is poured, and the screw is replaced. The wearing out of threads of the screw does not occur very often.

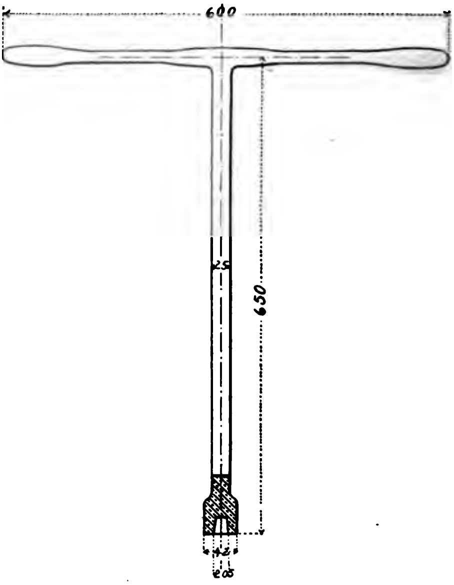

FIG. 46.—Key used on European railways to turn screw-spikes into position.

It is impossible at this time to give any exact and trustworthy information as to the relative cost of maintenance of tracks equipped with ordinary spikes and with screw-spikes. In view of the fact that the screws do not work out of holes, as do the spikes, which means a less frequent replacing not only of fastenings, but of ties, it would appear that the cost of maintenance would be very much lower for the screw than for the spikes, and the condition of the track generally better. The first cost of putting the screws into position is somewhat higher than that for placing spikes. This is principally due to the longer time which the operation takes.

As already described, the method of putting in the screws used on the European railways requires an ordinary key operated by two men. (Fig. 46.) It was foreseen that this would probably prove too slow for American conditions, and on that account a machine was devised which would allow of a more rapid screwing in than with the laborious horizontal machine. Such a machine is the one illustrated in figs. 48 and 49. The detailed design for this machine was drawn by Prof. A. L. Smith, of the Worcester Polytechnic Institute, Worcester, Mass.

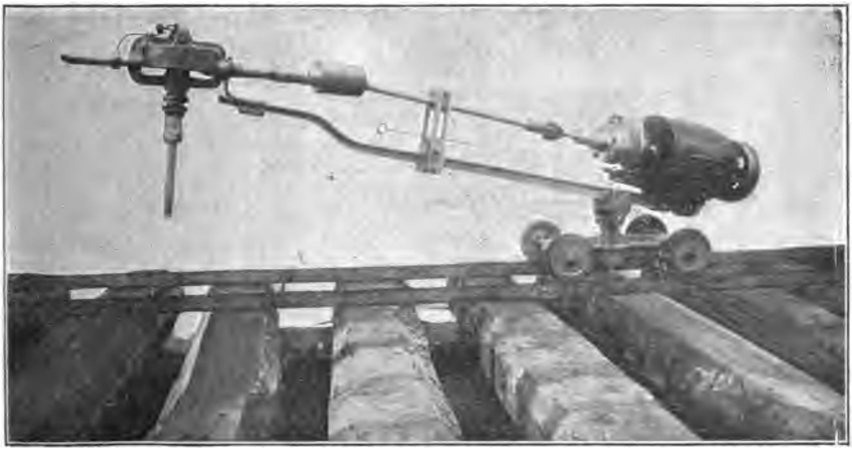

FIG. 47.—Electrical machine for inserting dowels or screw-spikes.

This machine may be described as follows: In figures 48 and 49 (A) is a tripod frame, 2 feet of which (E) and (F) are clamped to the rail, while the third foot (D) rests on the tie. The tripod is adjustable, so that it may be used on different sizes of rails. Its adjustability is such as to permit a vertical position of the sliding column or sleeve (B) and the rotating shaft (C) for all sizes of rails to which the machine is adapted. To allow of this adjustment for different sizes of rails and to allow for variations in the level of the upper surface of the tie, the foot (D) is made adjustable on the leg (L). To allow of adjustment for different sizes of rails the two parts (E) and (F) of the frame have adjustable slide blocks, as shown at (G) and (H). These slide blocks can be adjusted so as to prevent motion of the machine crosswise on the rail, and also so as to locate the axis of the rotating shaft (C) in its correct position relative to the flange of the rail. The slide block (H) has a protecting arm (K), which supports a swinging piece (I). Attached to the piece (I) is an ajustable screw (J) which permits the hook (IJ) to be adjustable for different sizes of rail heads. The object of the combined hook (IJ) is to prevent the tripod foot lifting from the rail. When the machine is canted on the rail by raising the leg (L), the hook (IJ) by action of gravity swings free from the rail, and the machine can be slid along the rail. On dropping the leg (L) back to its original position, the hook (IJ) swings back to its original position by gravity, and then clamps the machine to the rail.

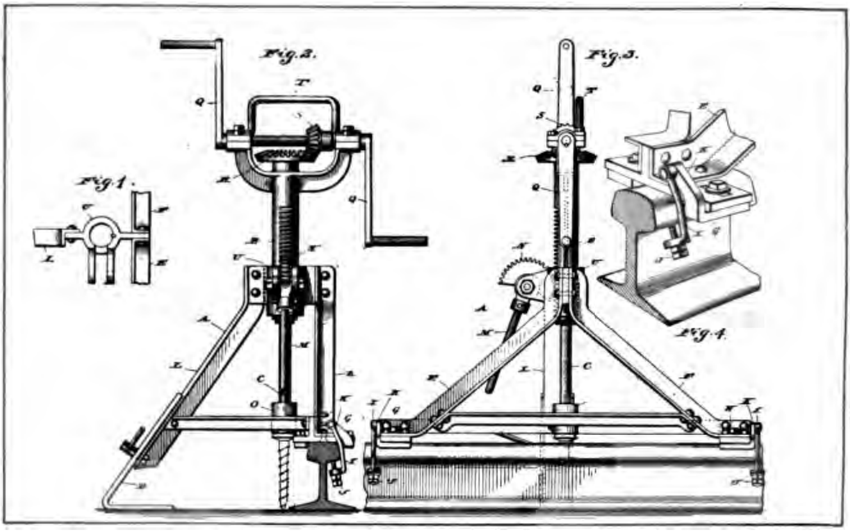

FIG. 48.—Working drawings of machine for putting screw-spikes into a tie.

The machine having been placed in its proper position on the rail, the lever (M) is depressed, thereby rotating the gear (N) and raising the column or sleeve (B) by means of the rack cut on the surface of (B). The column or sleeve (B) can slide in the head (U), but is prevented from rotation by a key fixed in (U) and engaging with a groove in (B). The shaft (C) can rotate in the column or sleeve (B), but can not move endwise therein. When (B) is raised, (C) is therefore raised with it. On the end of the shaft (C) is a socket (O), which fits the shank of the drill or the head of the screw-spike.

The drill or screw-spike having been placed in position in the socket (O), the lever (M) is raised enough to bring the point of the drill or screw in contact with the tie. By turning the crank (Q), the gear (S) is rotated. Gear (S) rotates gear (R) and shaft (C), to which gear (R) is rigidly fastened. As shaft (C) rotates, the drill or screw is fed downward by weight of the parts attached to it, assisted by an upward pull on the lever (M). The workman grasps the handle (T), thus steadying the machine and himself as he turns the crank with the other hand.

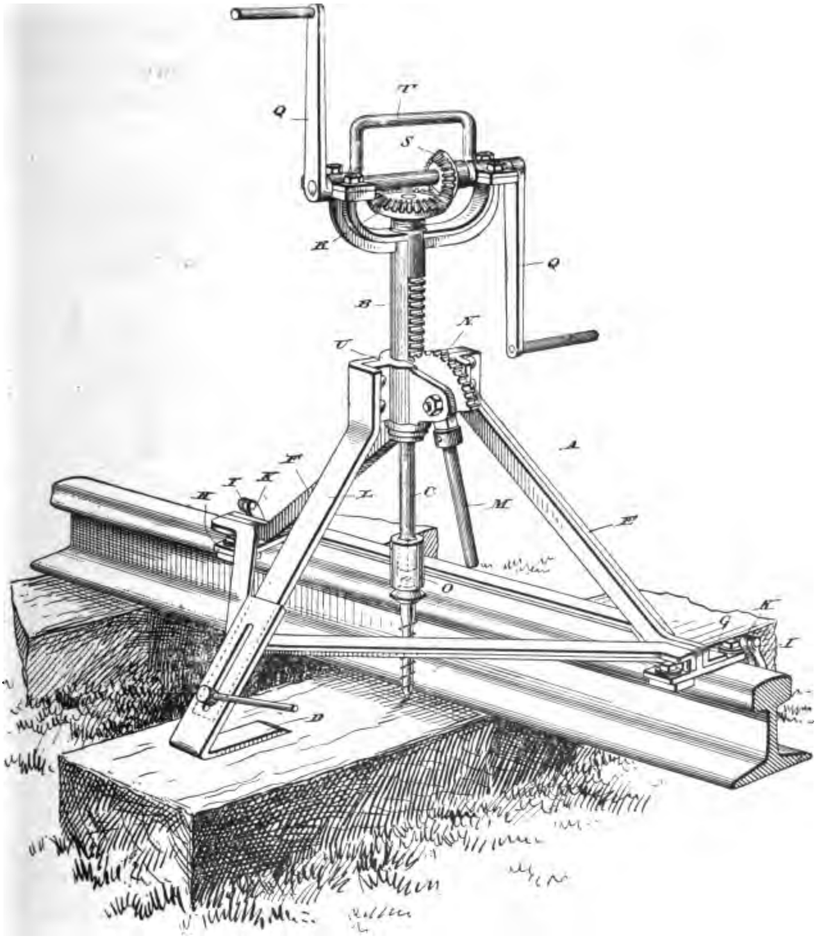

FIG. 49.—Perspective of screw-spike driving machine in operation.

This machine is not confined to hand power for its motive force. It is now being made at the Washburn shops of the Worcester Polytechnic Institute, Worcester, Mass.

A recent test made on the Pennsylvania lines with this machine showed that one could put in two screw-spikes while three spikes were being driven. While this operation requires a little more time than the placing of a spike, it must not be forgotten that the saving made possible by the absence of tearing the tie to pieces is very much greater than the loss of time. The chief objection which can be urged against the screw-spike at the present time is the matter of boring holes. In Europe this is done almost without exception at the treating plants, by the same machine which adzes the ties. In this country, with the numerous different rail sections used on almost every railroad, it will not always be practicable to bore holes in advance, and some method will have to be devised for boring holes out on the track by machinery. It is probable, however, that for stretches of new track, boring at the treating plant will be the simplest way to manage the problem.

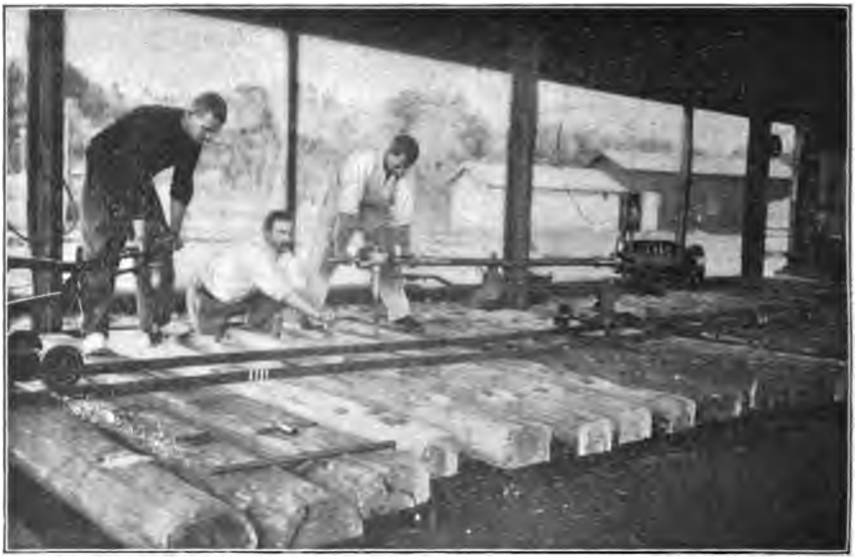

FIG. 50.—View of machine used for putting in dowels on the Midi Railway, in France.

Where single ties are renewed it will be possible to bore holes with the machine used for putting in the screws. All that will be necessary will be to replace the screwing key with a bit. It is expected that the tests now under way with screw-spikes on various roads in this country will enable a close estimate to be made of the actual cost of placing screws compared with that of putting in spikes.

Reference should be made here to other possible machine devices for putting in screws. In fig. 47 a machine is shown which is at present used for putting in dowels, but which has also been used for screwing in spikes, as shown in fig. 50. This machine requires an electrical current. There ought to be no great difficulty in obtaining this by means of a small motor attached to an engine. Such a machine would be necessary in the case of new construction work or where long stretches of track are to be laid.

COST OF SCREW-SPIKES.

The screw-spikes manufactured in France and Belgium now cost about $4.45 per 100 kilos (220.46 pounds). Each spike weighs about 18 ounces. It is expected that these screw-spikes will cost about 4 to 4½ cents in the United States.

CONCLUSIONS AS TO SCREW-SPIKES.

First. The type of screw-spike which it is believed in the light of European experience will give the best service is that shown in fig. 38. This screw combines the advantages of ease of making, cheapness, and longer service than the other types of screws, and, moreover, wears out the thread of the wood less than closer wound screws. Tests with this screw are now under way on several of the roads in the United States.

Second. It is suggested that these screw-spikes be placed in two ways—four screws per tie and six screws per tie—according to the European model.

Third. As the screw-spike forms one of the proposed modifications of the present method of fastening, it is desirable that screws be tested on a broad-based rail without any plate, and also with steel and with wooden plates.

Fourth. In buying screw-spikes, only such as show a sufficient strength of head should be accepted. Most screws hitherto used have not had strength enough to stand the vertical blow upon the head.

Fifth. Recent tests show that the ratio of the holding power of the screw-spike as compared with the common spike ranges from 1.87:1 for white oak to 4.63:1 for longleaf pine.

The result of lateral impacts shows that under the action of a side blow such as comes on a rail a common spike is pulled out from one-fourth to one-half inch, while the screw-spike is not perceptibly started.

TIE-PLATES.

REASON FOR USING PLATES.

It has already been said that the functions of the tie-plate as first used were twofold—to distribute the load from the rail to the tie, and to prevent the mechanical abrasion of the tie so far as possible. It was found that the rails with a narrow base cut into the tie considerably, and that by using a broad, flat plate this cutting could very largely be stopped. The experience of the last thirty years has shown that on the harder timbers this is without question true. With the increasing width of base of the rails which have been coming into use during recent years, tie-plates on timbers like white oak have become no longer absolutely necessary, except where there is a severe strain, as on curves. On the softer woods, however, it is still necessary to use tie-plates to prevent wear. But such tie-plates must be materially wider than the base of the rail to be of any good.

FORMS OF PLATES.

Most plates have been made with the idea of being anchored to the tie so as to prevent the communication of the motion of the rail to the plate. As a result, we have a large number of different forms of plates provided with prongs, spines, or flanges on the bottom, which are pressed into the tie either by the weight of the passing load or before the rail is laid.

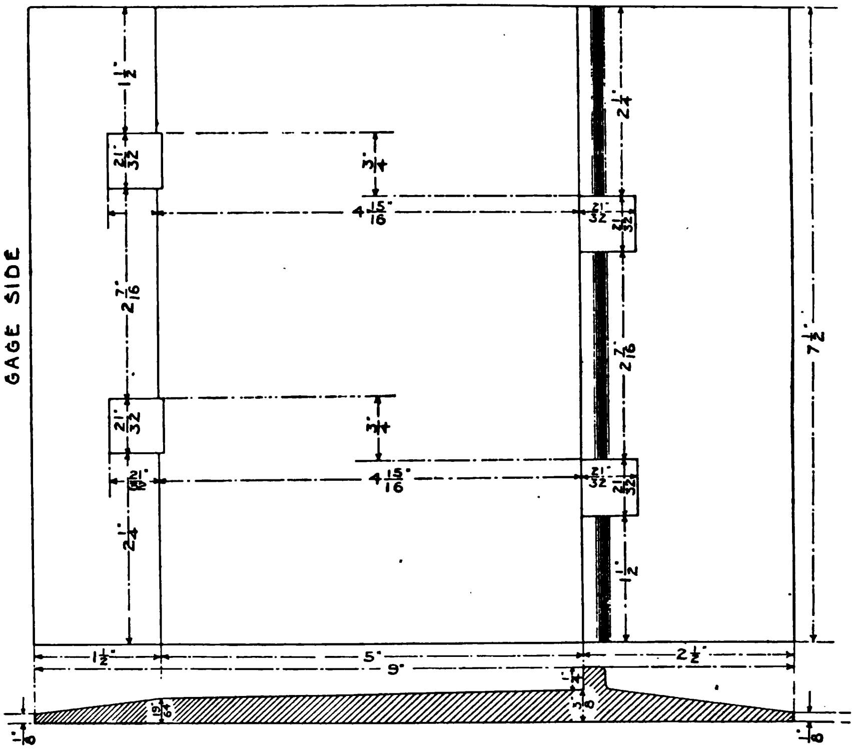

FIG. 51.—Tie-plate in use by the Southern Pacific Railroad.

The objections which have been made to tie-plates are, first of all, that they buckle severely. This, however, has taken place only when the plates were too thin. The chief objection which is made to plates at this time, particularly in connection with the use of softer woods, is that not only do they not aid in preventing the wear of fibers, but they actually assist the rail to wear. This is well illustrated on Pl. II, fig. 2, showing a tie-plate which has been in position on a loblolly pine tie for about four years. The constant rocking motion of the rail, which had become very marked as the spikes were pulled from the soft wood, had transmitted itself to the tie-plate, and when a load passed over the rail the tie-plate moved back and forth in unison with the rail. It was not long before the soft fibers of the loblolly pine suffered under this treatment, and in the course of time so great did the abrasion and crushing of the fibers by the plate become that a considerable

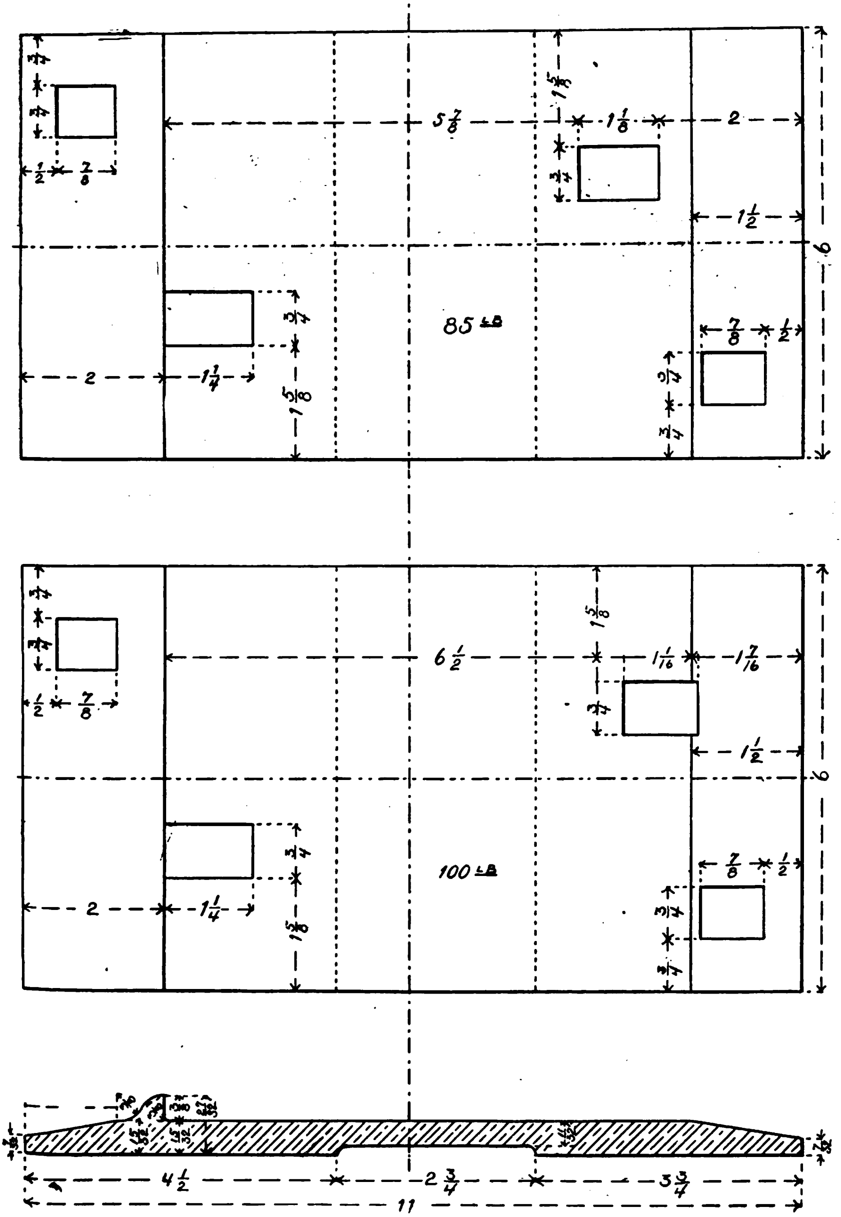

FIG. 52.—Type of flat tie-plate in use on the Pennsylvania Railroad.

hole was made under the plate, in which water gathered. The plate gradually sank down into this hole, as shown in the illustration. When

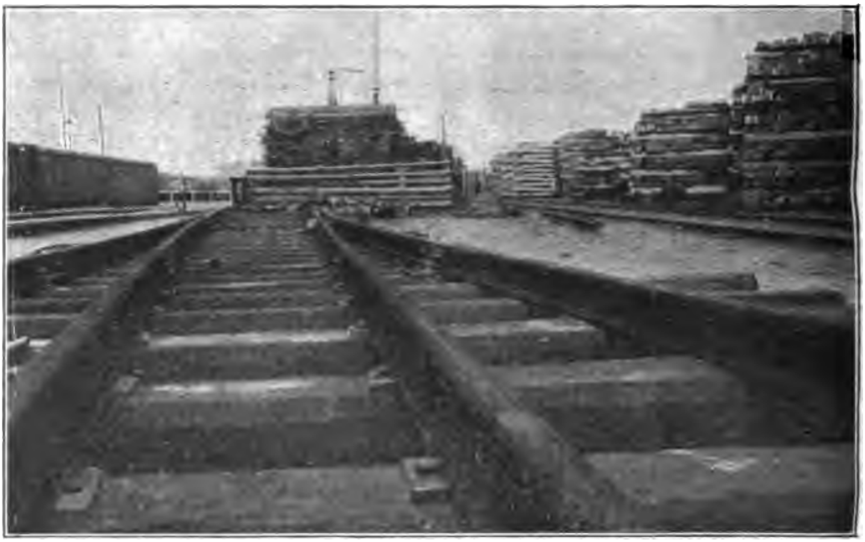

FIG. 53.—Track under construction on the Prussian Railway near Berlin, showing the relation between the rail, flat tie-plate, and screw-spike.

the tie was removed it had disappeared in the wood, and the base of the rail was resting on the outer edges of the tie beyond the plate.

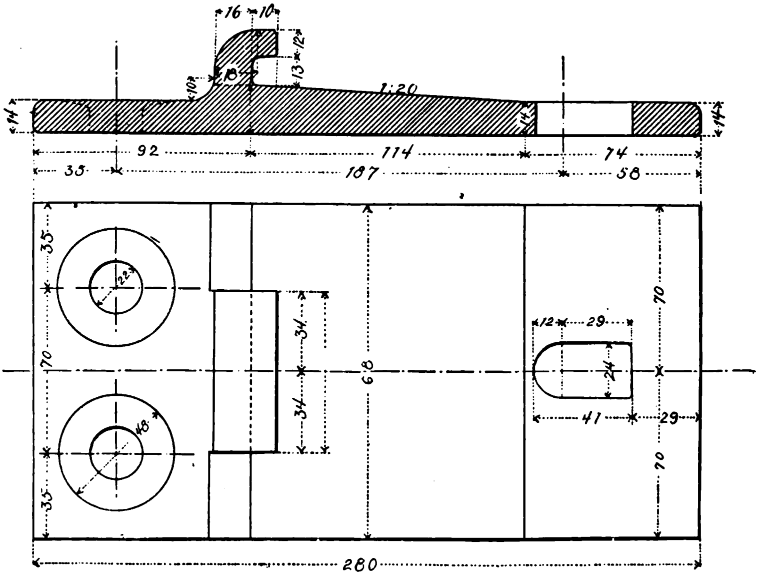

FIG. 54.—Joint tie-plate used by the Austrian state railways.

This tie had been treated with zinc chlorid. The water which gathered under the tie-plate leached out the salt, and as a result decay started on both sides of the plate, as the illustration shows. The tie had to be removed, although the rest of it was perfectly sound.

Pl. III presents further examples. Fig. 1 is a section of a treated loblolly pine tie from Texas, which had to be removed because the tie had decayed under the plate; fig. 2 shows a section from the middle of this same tie, with no sign of decay discoverable. Instances of this kind are by no means rare, and they seem to indicate strongly that where a plate is to serve as a protection against wear it must be of a kind which will not itself wear out the wood.

The objection which has been made to all flat plates is that it is difficult to keep a track in gauge when they are used. The Southern Pacific Railroad Company have used a flat plate very extensively since 1892. The maintenance of way department states that these plates have given excellent service, that they are certainly superior to the small flange plates first used, and that it is thought they will prove as good as the heavier flange plates now in use. Fig. 51 shows a type of flat plate now in use on the Southern Pacific.

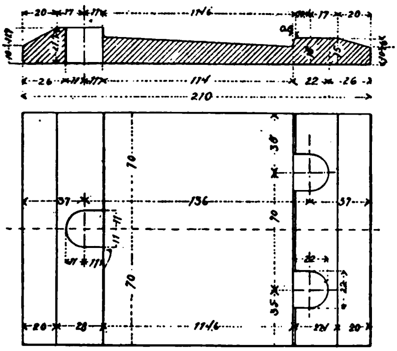

FIG. 55.—Intermediate tie-plate used by Austrian state railways.

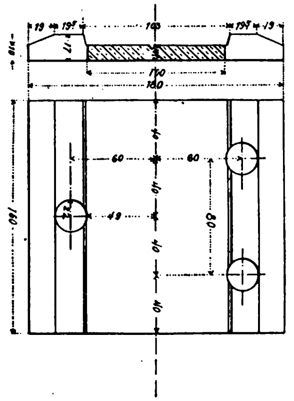

FIG. 56.—Intermediate plate, Italian type (Mediterranean Railway).

The Pennsylvania Railroad has been using a tie-plate for several years, of which it says:

> We adopted the flat plate [fig. 52] because we found that too thin plates would bend up. On the plan where two cutting edges are shown beneath, we reduced this to a minimum, making these edges only large enough to indent the wood without damaging it much and placing it as much under the rail as possible. This was the early plan, adopted years ago, and a continued test convinced us that we should follow the experience of the English roads by having no projections, prongs, or cutting edges to the tie-plate. * * * We are now satisfied that a tie-plate should not have any projections; that on the contrary it should be plain and damage the tie as little as possible. These tie-plates cost 14½ cents for 85 and 100 pound intermediate tie-plates and 18.8 cents for 85 and 100 pound joint tie-plates. We have noticed no tendency in buckling with this thickness of plate. We use tie-plates on all classes of oak, chestnut, yellow pine, and all woods purchased in our cross-tie specification. There has been no difficulty in maintaining the gauge owing to the absence of devices

for anchoring plates in the wood. On the contrary, we have used plates extensively on sharp curves where formerly we had the ordinary rail brace on sharp curves. This rail brace does not continue to fit up against the head of rail. It gets loose and out of position, and we have taken the brace off and used tie-plates, and the shoulder on the outside of the rail brace we have used, and there is no device for anchoring the plate to the wood more than the spikes.

The types of plates used in Europe are without exception flat plates. In the view of a piece of track under construction on the Prussian Railway, shown in fig. 53, it will be noted that a broad, flat plate is used. Figs. 54 to 57 represent plates used by several European roads at the present time. Fig. 54 represents a joint plate of the Austrian state railways, and fig. 55 an intermediate plate used by these roads. Fig. 56 shows an intermediate plate of the Italian Mediterranean Railway, and fig. 57 an intermediate plate of the Bavarian state railways. The general tendency abroad has been toward adopting more and more rigidly flat plates, with firm fastenings. The almost universal adoption of this principle is very striking at the present day.

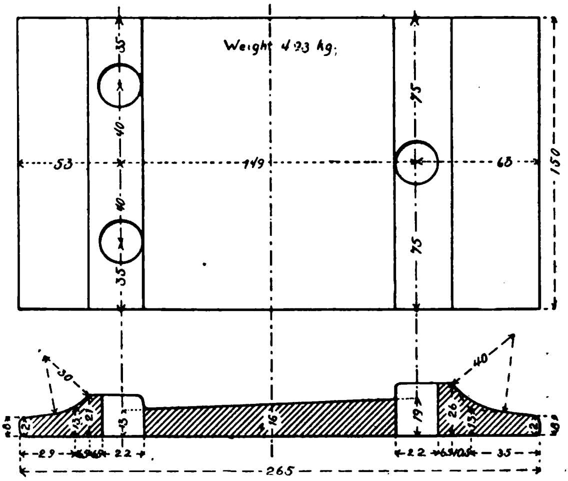

FIG. 57.—Intermediate plate, Bavarian state railways.

WOODEN PLATES.

Some of the European roads, notably the French Eastern, are using a novel form of tie-plate, and have been doing so for a good many years with the greatest success. This tie-plate consists of creosoted wood about one-eighth inch in thickness, 8 inches long, and of the exact width of the base of the rail under which the plates are to be used (on the French Eastern Railway main lines, 5 inches). This plate corresponds practically to the shim frequently used in this country, only that it is very much thinner. The ties are adzed at the treating plant so that a place is left for this flat wooden shim. When the track is laid the shim is placed in position (fig. 45) and screw-spikes are screwed into the tie. Their pressure holds the plate firmly between the base of the rail and the tie. In fig. 45 the wooden tie-plate is represented by the thin unshaded portion between the rail and the tie. It is exactly the width of the rail. In the course of time the motion of the rail wears out this shim, and a new one is substituted by giving the screw-spike one or two upward turns. A new plate is then shoved in endwise and the screw is fastened. The length of life of one of the wooden shims on main-line tracks, such as that of the French Eastern from Paris to Strassburg, is about one and one-half to two years. These shims cost approximately $2 per thousand, and are made of poplar or any other hard wood, and creosoted.

The theory upon which the use of this wooden plate is used may be briefly stated. The principal function of the plate has been said to consist of preventing the wear of the fibers of the tie immediately under the rail base. This wear consists in the actual breakage of the wood fibers under a grinding and tearing action rather than in crushing them.

In considering the function of the tie-plate we have three bodies to deal with—the tie, the tie-plate, and the rail. Motion might conceivably take place either between the rail and the tie-plate or between the tie-plate and the tie. When a metal tie-plate is used on the hardwood tie, and is successfully anchored in it, the tie-plate and the tie act as one body, over which the rail moves back and forth. As soon as the tie-plate loses its holding power, however, the chances are that when the rail moves across the tie the tie-plate will oscillate back and forth in unison with the rail. This results in breaking the wood fibers underneath the plate. Where a wooden plate is used it adheres so closely to the wood that when the rail moves across the tie the wooden plate and the wooden tie are liable to act as one, even though the tie-plate is not anchored to the tie.

This means that any wear will probably be at the expense of the plate instead of the tie. The wooden plate is cheap, and can be replaced at no great cost. By its use the wear caused by the steel plate in the softer woods is practically entirely avoided. Ties which have been in position with these wooden plates for many years on the French roads show a most remarkable absence of wear of any sort. The wooden plates have the further advantage that they are quickly and easily applied, and that they are extremely cheap. They can, however, be used only under a fastening which holds the base of the rail strictly against the tie, such as the screw-spike. Tests of these wooden plates with spikes are, however, now under way on the Atchison, Topeka and Santa Fe Railroad. The plates are made a little wider than the rail, and are nailed to the tie with several small nails.

Arrangements are now being made for testing these wooden plates in a number of stretches of track in this country. Their exact dimensions have not yet been fully decided upon, and will probably have to be considerably modified to suit American conditions. The dimensions of the plate now under test are one-fourth inch thick, 6 to 7 inches long, and the width of the rail base under which they are used. The plates are made of beech, oak, poplar, and red gum, and are heavily creosoted. Several other materials have been tried for plates, using the same idea as that on which the wooden plates are based. They are chiefly of felt and horse hair, but have shown no superiority over the wooden plates, and are nowhere in general use.

RECOMMENDATIONS AS TO TIE-PLATES.

First. For the softer and inferior woods it is recommended that, pending experiments with wooden tie-plates in this country, wherever possible a flat steel tie-plate be used without spines or flanges on the base of the plate. The flat plates should preferably have a flange on the upper side, to hold the outer edge of the base of the rail.

Second. It is recommended that tests be made with wooden tie plates of the following dimensions: One-fourth, one-half, and five-eighths inch in thickness, 6 to 7 inches long, and the width of the rail base under which they are to be used. These tie-plates should be made out of soft woods, and should be fully creosoted.

DOWELS.

Attention was called above to the fact that one of the greatest difficulties with soft timbers lies in the fact that the wood around the spikes wears out with considerable rapidity after the new tie has been put in service. This wearing out not only destroys the tie, but also makes the track unsafe, since the rails are no longer held to the tie. A recent invention by a French engineer has already shown such remarkable results in the way of preventing wear around the spike that it is deserving of study and trial.

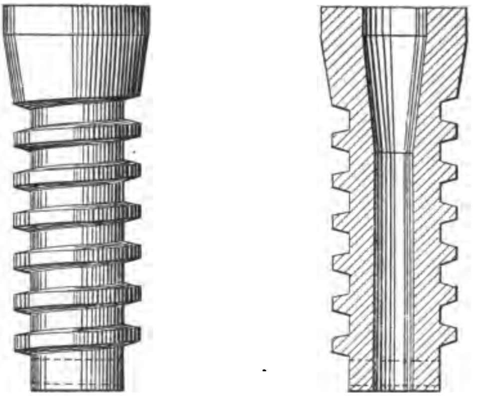

FIG. 58.—Screw dowels, shown in face view and in longitudinal section.

In 1896 this engineer called attention to a cylindrical screw dowel which he had devised for use with softwood ties. This dowel (illustrated in fig. 58) consists of a cylindrical piece of wood formed into a screw with a very wide thread.

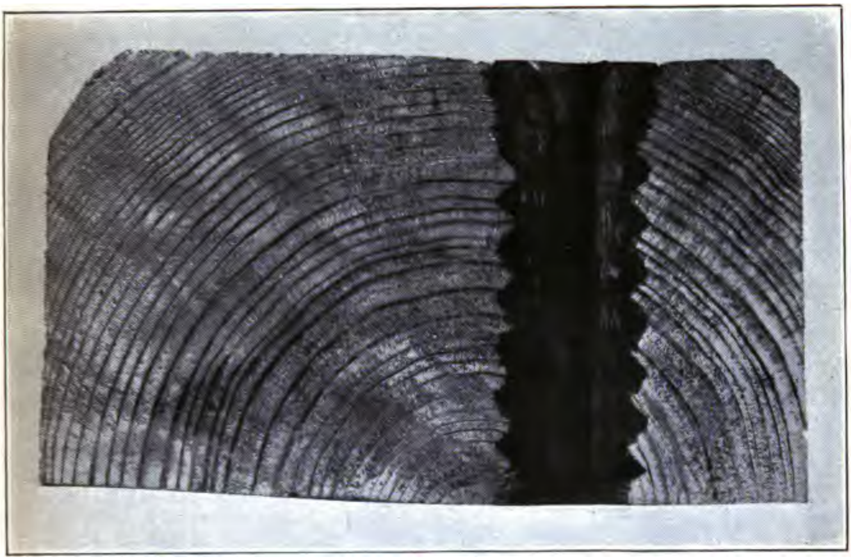

FIG. 1.—CROSS SECTION OF PINE TIE THROUGH THE DOWEL.

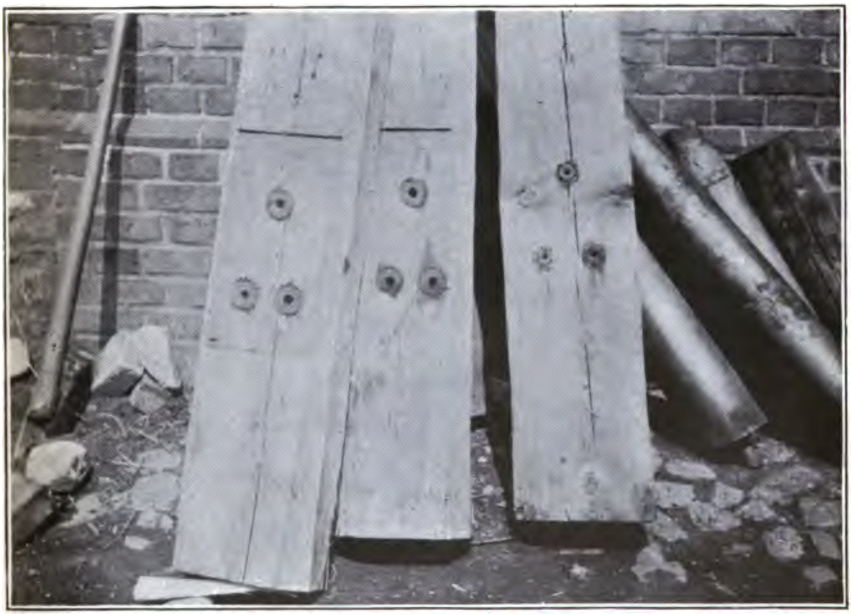

FIG. 2.—THREE TIES OF BALTIC PINE ON THE PRUSSIAN STATE RAILWAYS, BERLIN, SHOWING THE MANNER IN WHICH SCREW DOWELS APPEAR IN THE TIE WHEN READY TO BE SHIPPED.

TIES WITH SCREW DOWELS.

At the upper end the dowel is somewhat larger than at the lower, so that when it is screwed into place water can not enter between the dowel and the tie. A hole is bored in the center to admit either a screw-spike or an ordinary spike. The dowels are made out of carefully selected pieces of such woods as beech or birch, which have been seasoned for several years, and are heavily creosoted. The dowels are screwed in by hand where only a small number are needed, but where the number is large machinery is used. A series of ingenious instruments (figs. 60, 62, 64) have been devised for setting the dowels. A cylindrical hole is first bored into the tie of a diameter equal to the body of the dowel (fig. 59). A shaper (fig. 60) then forms the screw thread in the tie (fig. 61), and the dowel is screwed in by means of the instrument shown in fig. 62. The projecting top of the dowel (fig. 63) is then shaved off even with the tie with a shaping knife (fig. 64). The tie provided with the dowel appears as in fig. 65 and on Pl. V, figs. 1 and 2. Fig. 66 shows a dowel with the screw-spike in position. For setting large numbers of dowels electrical machines are used. Such a machine is shown in figs. 47 and 50. These machines have for several years been in use at the treating plant of the French Midi Railway. Fig. 50 shows the work of setting dowels in actual operation. It is an extremely simple process, and is performed before the ties are shipped out on the road. The machine figured consists of a small 5-horsepower motor with a flexible shaft, mounted on four wheels, the gauge of which can be varied at will. In actual practice a 5-horsepower and a 3-horsepower machine are used. The 5-horsepower machine bores the holes and shapes the screw-thread, and the 3-horsepower machine screws in the dowels and cuts off the heads. One man can easily manipulate one of these machines. The manner of working the machine is evident from fig. 50. Near

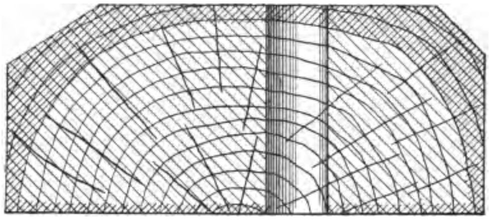
FIG. 59.—Cross section of tie, showing hole bored for screw dowel.

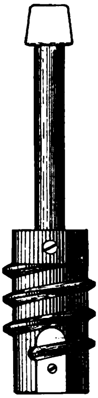
FIG. 60.—Shaper used to cut the screw thread in the wood for the insertion of the screw dowel.

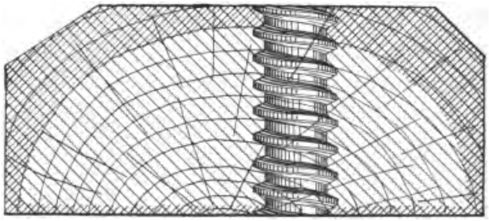
FIG. 61.—Section of tie, showing screw thread ready for the dowel.

Bordeaux, in southern France, an average of 2,400 ties per day are provided with six dowels each. With hand tools the German company estimates that one man after brief practice can provide 15 ties with six dowels per tie in one day. Since four men can work with one set of tools, one man boring the hole, one cutting the screw thread, one screwing in the dowels, and one cutting off the top, it is possible to provide 80 to 90 ties with six dowels each in a day with two sets of hand instruments. From the greater rapidity with which Americans work, it will probably be possible to increase this number here.

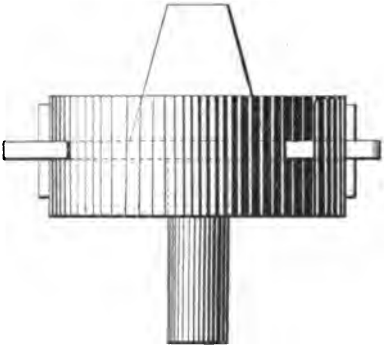

Fig. 62.—Instrument used for screwing the dowel into the tie.

One of the greatest advantages of the dowel lies in the fact that it can be applied to ties in which the spike holes have worn out. This is done by increasing the size of the old spike hole to the necessary diameter of the dowel and placing the dowel in position much as for the new tie. Fig. 67 shows a spike around which the wood is decayed. When this spike has been removed and the dowel put in, the tie appears as in fig. 66.

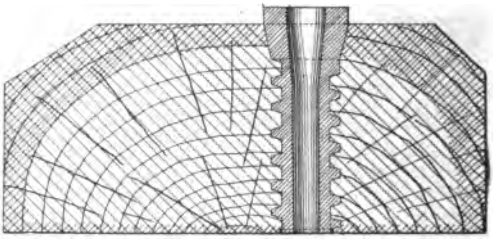

Fig. 63.—Screw dowel in position in the tie.

The dowels fit very tightly into the wood. The great lateral pressure against the wood fibers is illustrated by the fact that when some ties which had been provided with dowels for five years were sawed through the pieces of the dowels were sprung out from the tie. Pl. V, fig. 1, shows a dowel and new tie cut through the middle. The dowel had been in position in this tie about three months. It will be noted that some of the creosote with which the dowel had been treated had already penetrated laterally into the soft wood of the tie. Great stress is laid upon this, for it proves that the wounding of the tie made by screwing in the dowel is of so light a character that not only is there little space for water to enter, but the dowel itself helps to make the wounded surface impervious to the action of water, and protects it against fungi. Pl. V, fig. 2 shows both top and bottom surfaces of three ties of the Prussian Railway newly

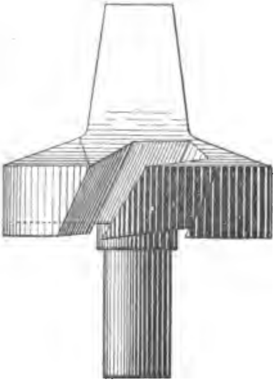

Fig. 64.—Knife used to cut the dowel off even with the tie.

provided with dowels. The soaking of the tar oil into the wood surrounding the dowel is noticeable.

A large number of tests have been made to show the higher resisting power to both vertical and lateral pulls of screw spikes and spikes when inserted in the dowel. Figs. 68 to 71 show a result of tests made by the German Government. Figs. 68 and 70 show the resistance to vertical pressure in pounds for dowels inserted in both old and new ties, while figs. 69 and 71 show the lateral resistance. A very much greater resisting power of the spike or screw spike within the dowel is at once evident. A further valuable fact is that not only does the dowel protect the surrounding wood against the wear of the screws or spikes, but the heads of the dowels serve partially as tie-plates. The experience of the last five years on the Paris-Lyons-Mediterranean Railway of France with soft French southern pine is worthy of note. On stretches of track over which an average speed of 100 kilometers (62.1 miles) was made, a number of old ties were provided with dowels in 1896, and at the same time a number of new ties without dowels were laid. In 1902 the new ties had already been worn out, while the old ties with the dowels showed practically no wear. If this should prove true in this country, it might be possible to do away with the expensive steel plates now generally in use. The following estimate (p. 70) made by a German engineer shows how the European engineers who have tried dowels look at the matter.

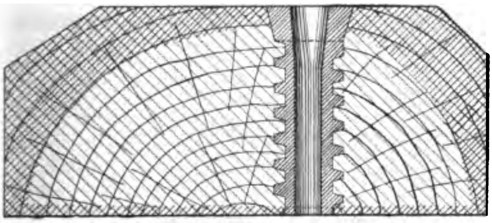

FIG. 65.—Cross section of tie with the dowel in its final form.

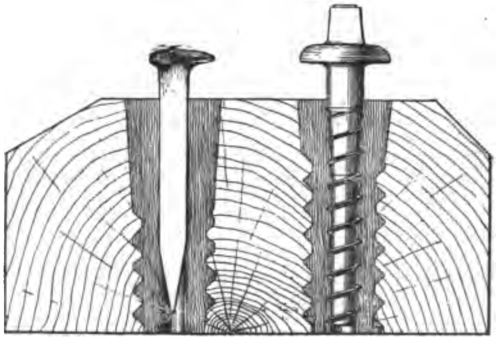

FIG. 66.—Relative position of the screw dowel to the screw-spike when in place.

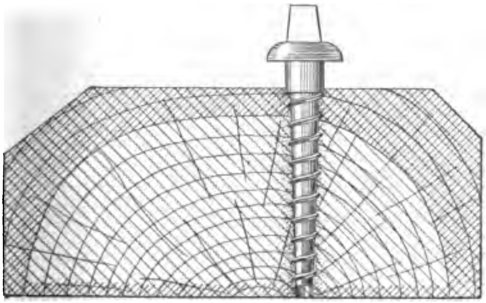

FIG. 67.—Screw-spike in position, with the surrounding wood decaying.

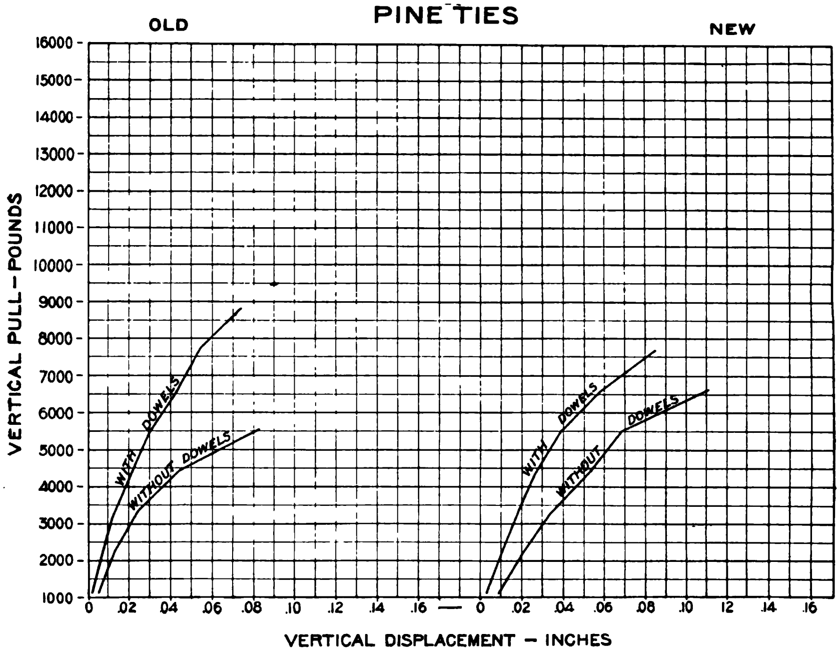

FIG. 68.—Comparative resistance to vertical pressure of screw-spikes in pine ties, old and new, with and without dowels.

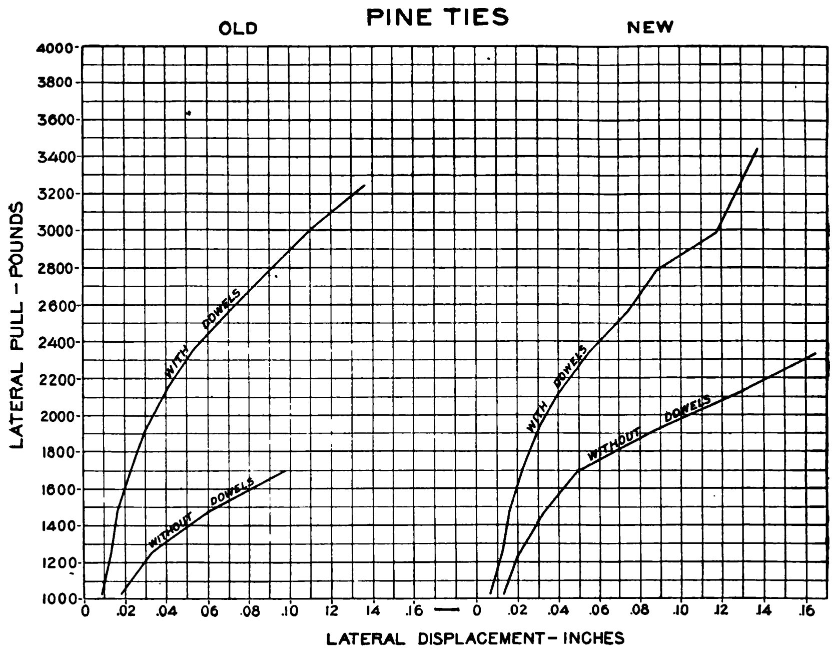

FIG. 69.—Comparative resistance to lateral pressure of screw-spikes in pine ties, old and new, with and without dowels.

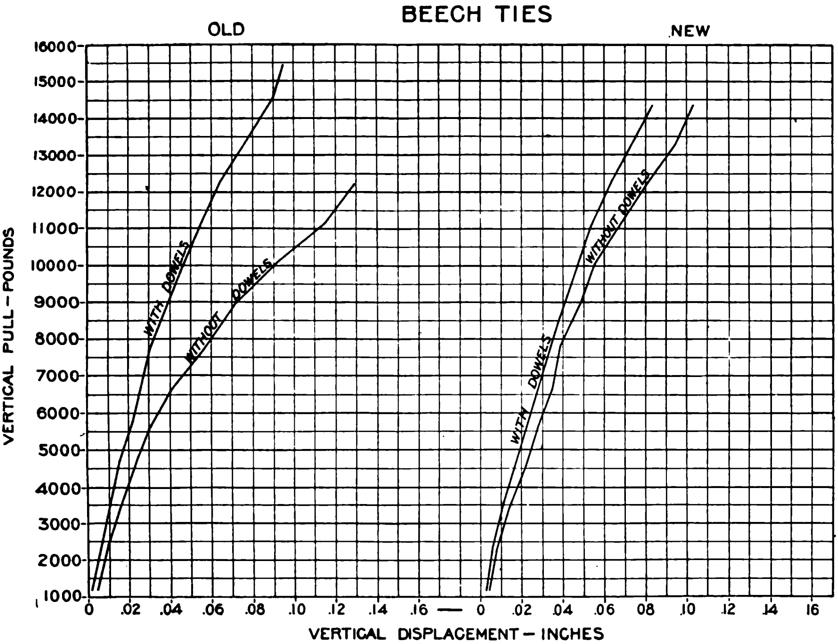

FIG. 70.—Comparative resistance to vertical pressure of screw-spikes in beech ties, old and new, with and without dowels.

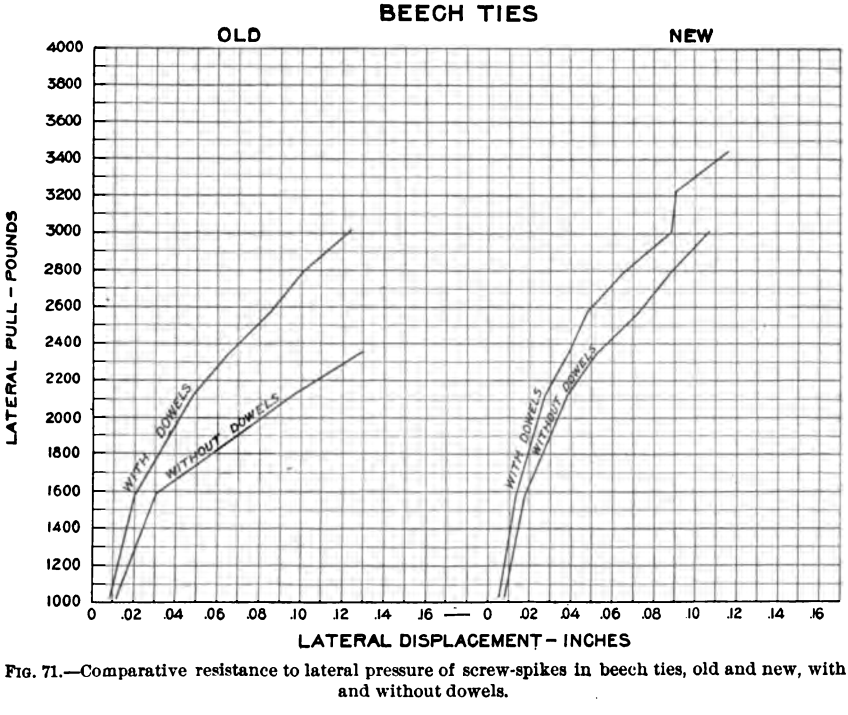

FIG. 71.—Comparative resistance to lateral pressure of screw-spikes in beech ties, old and new, with and without dowels.

Estimating the price of a treated pine tie, including the placing of the same, at 4 marks (95 cents), the annual charge at 3½ cents with interest would be about 55 pfennigs, if it is assumed that such a tie lasts ten years. The price of providing one tie with six dowels can be estimated at 1.10 marks (26 cents). If one uses old ties which have been taken out of the track and provides these with dowels instead of replacing the old ties with new ties, the cost of providing ties with dowels will already pay for itself after two years' use of a doweled tie. It has already been proved at this date that the increase in the length of life is very much more than two years. If the increased length of life be estimated at from eight to ten years, about 4 marks (95 cents) per tie will be saved.

The best proof of the high estimation in which Europeans hold the dowel is the great extent to which they are being adopted. The Prussian State Railway this year provided 350,000 old ties with dowels, and the Paris-Lyons-Mediterranean Railway of France has for several years been putting dowels in its ties. The same is true of a certain number of Spanish roads which have been putting in 250,000 to 300,000 dowels annually. On the Marienfelde-Zossen stretch, on which the high speed tests of the Prussian Government were made recently, all the ties were provided with dowels. The increased strength thereby given to the track is testified to by the military authorities in charge of track construction.

There can be no question but that the introduction of the dowel is one to be welcomed by all engineers. The great increase in holding power which it gives both to ordinary spikes and to screw-spikes can not be questioned, and any device tending toward increased stability ought to be welcome. The adoption of a device of this kind in the United States will depend largely upon the ease with which it can be applied. Their universal adoption will probably be a matter of some time, because of the large number of rail sections now employed. A careful investigation of European tracks which have dowels in position leads the writer to recommend a trial on an extensive scale with this new fastening, both with screws and with spikes. Arrangements are already made for putting a considerable number of dowels in various tracks in the United States. It is believed that the great problem of how to make a spike hold in soft wood ties as well as it would in an oak tie may at least be partially solved by the use of this device. If it turns out that it is possible to make a soft wood like loblolly pine or red oak serve the same purpose as the harder white oak or longleaf pine, an important step in the utilization of our forest resources will have been made.

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